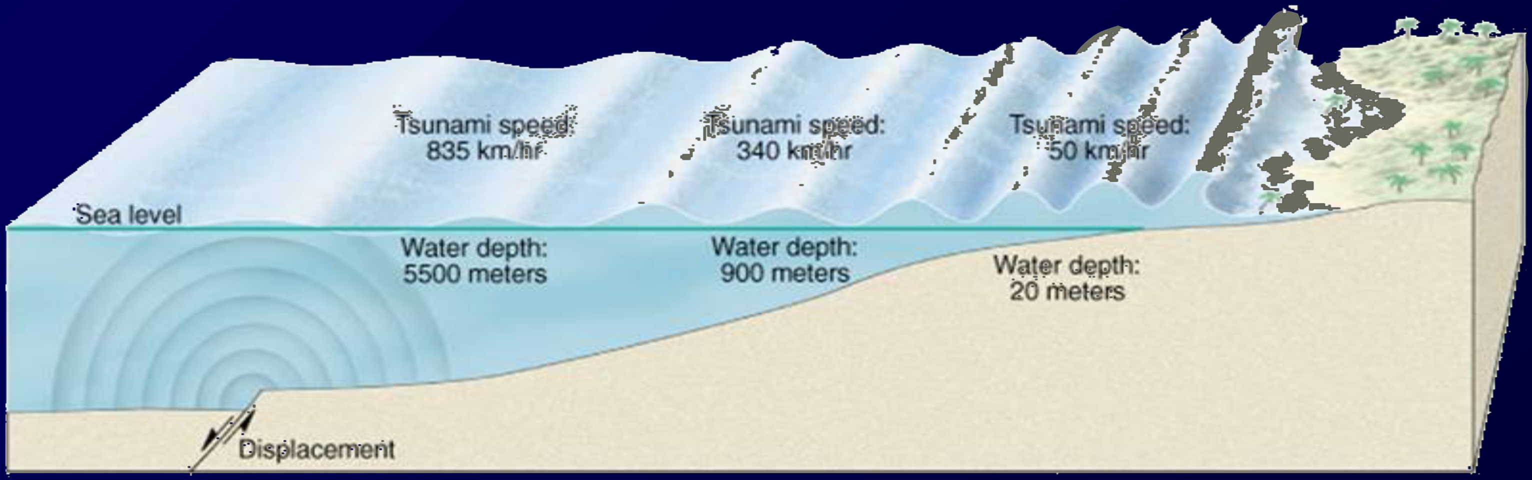
Tsunamis!

Ted Buehner
Warning Coordination Meteorologist
National Weather Service – Seattle/Tacoma

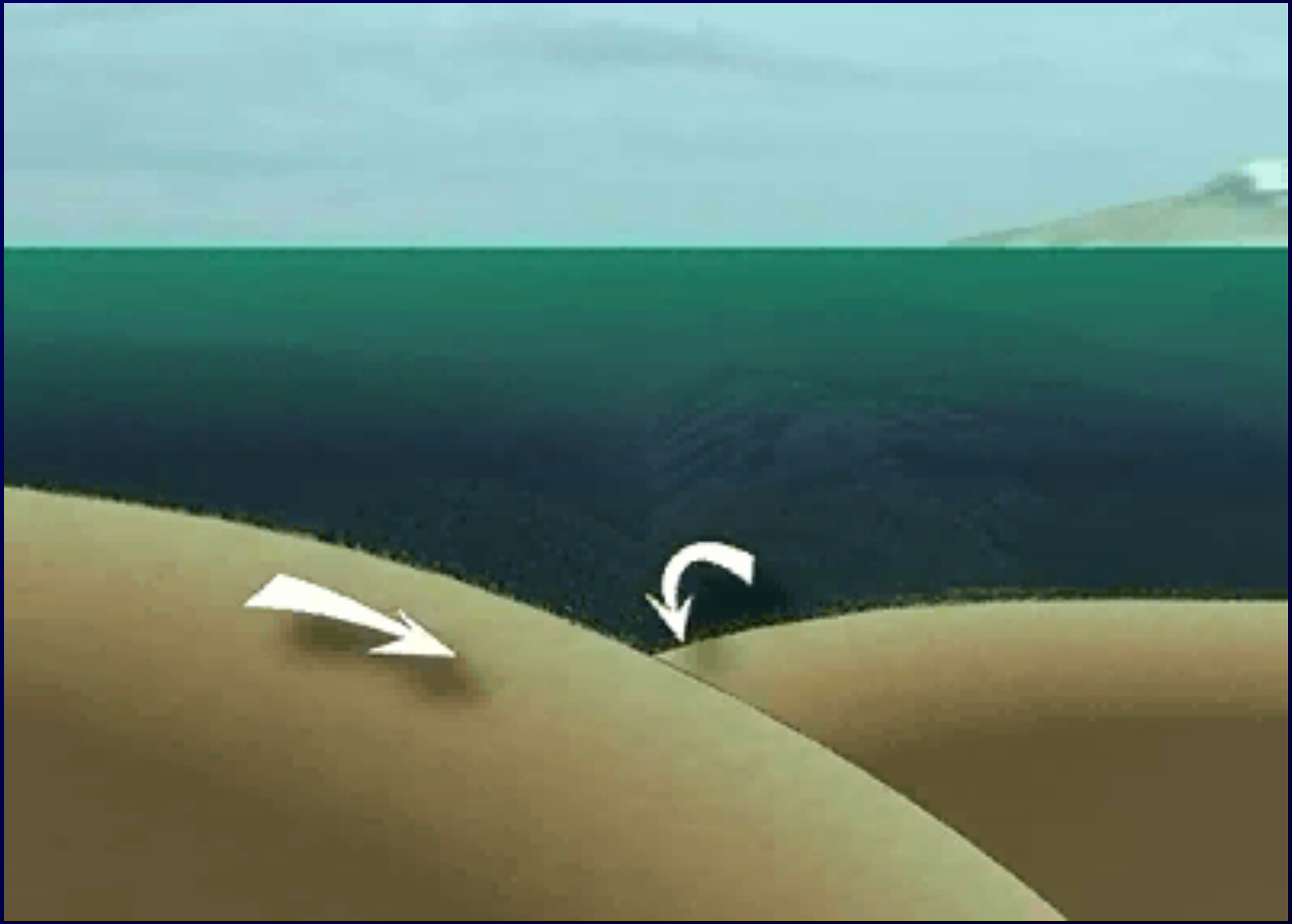
George Crawford
Earthquake Program Manager
Washington Emergency Management

What is a Tsunami?

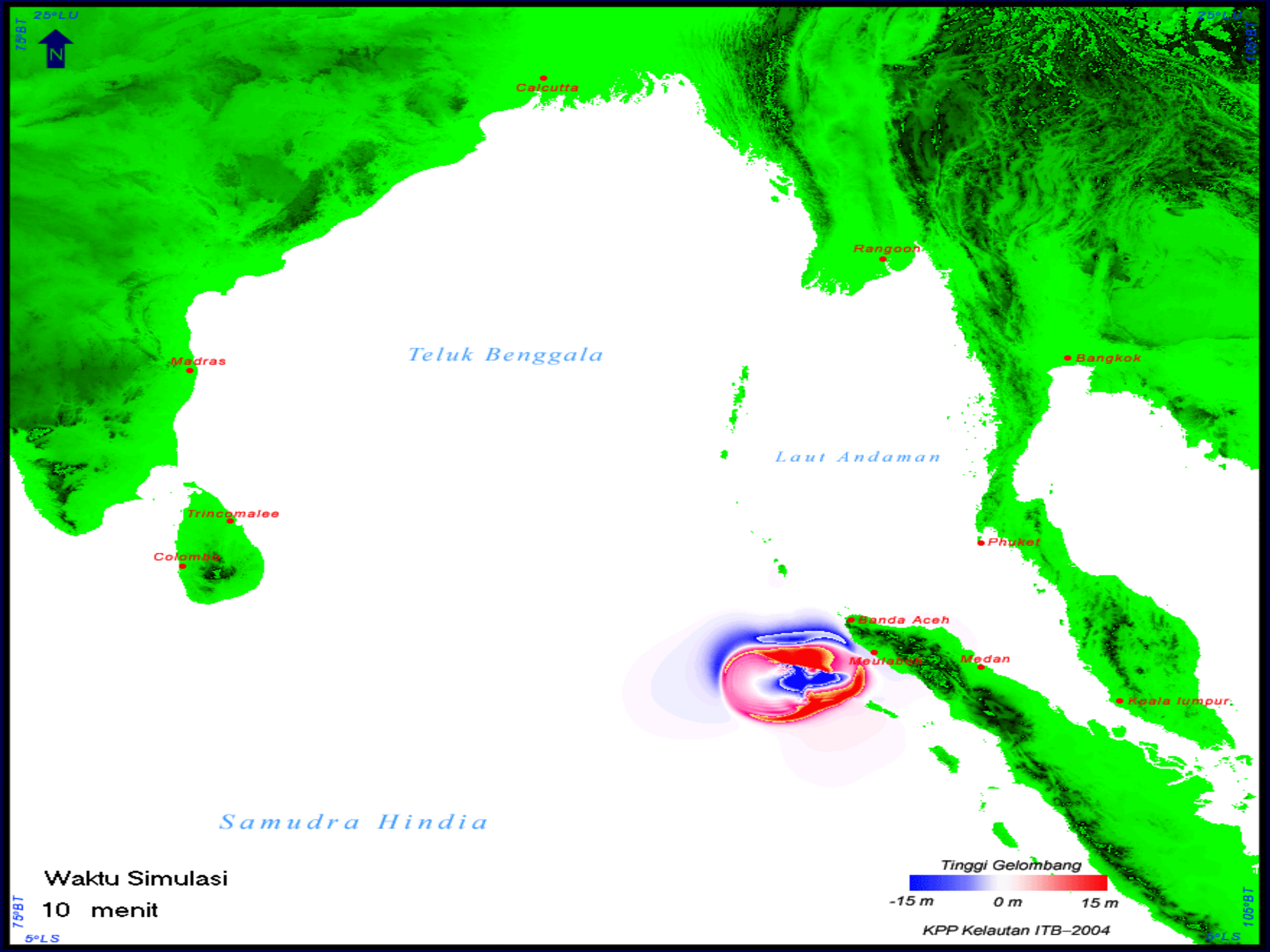


A tsunami is not a single wave, but a series of waves. Stay out of danger until an “ALL CLEAR” is issued by a competent authority.

Tsunami 101



Indian Ocean Tsunami



Indian Ocean Tsunami

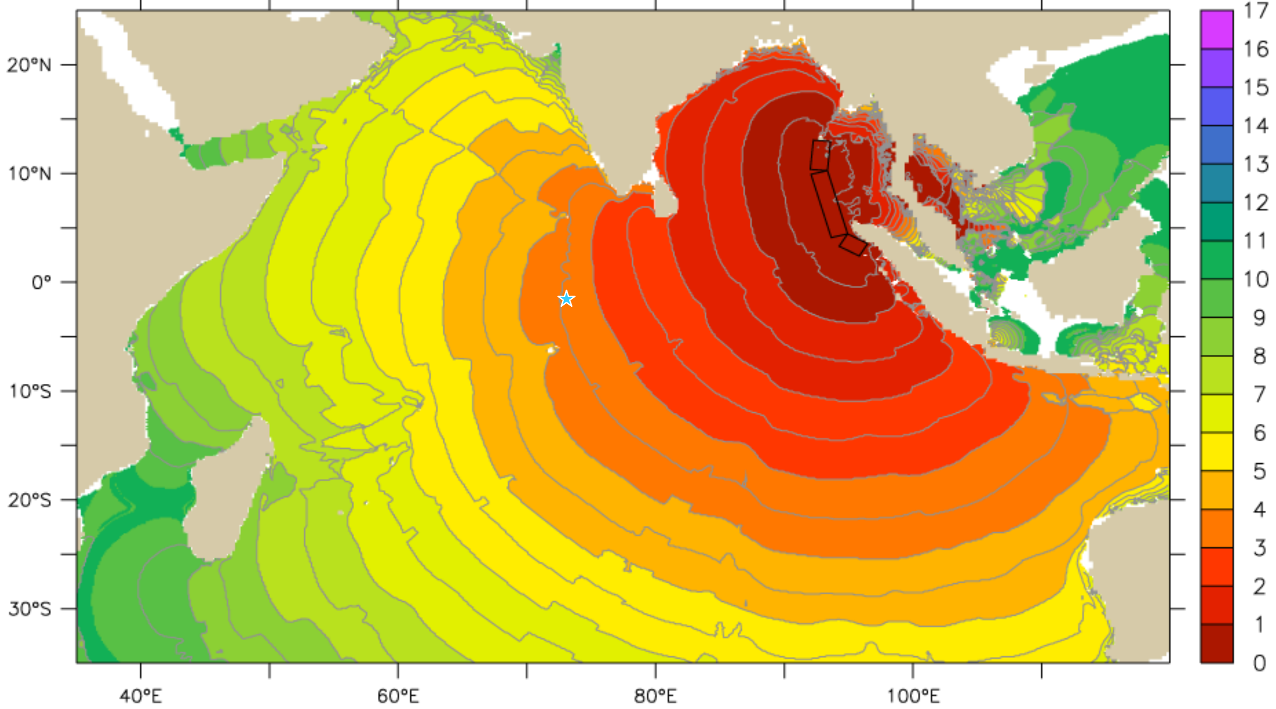
Wave Propagation in Hours

Facility for the Analysis and Comparison of Tsunami Simulations (FACTS)

Arrival Time of First Wave(hours) – 2004.12.26 Indonesian Tsunami

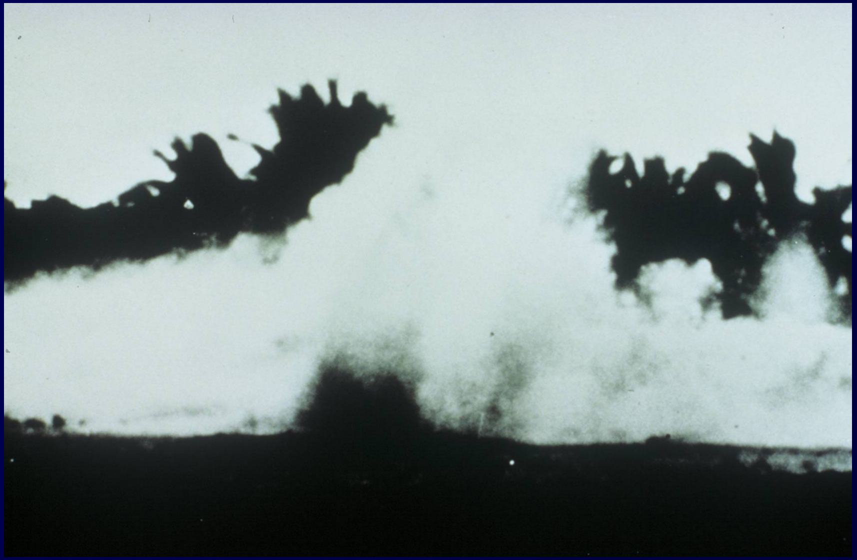
T (SECONDS) : –30 to 36030

Source: Mw 9.0 (4°N,95.7°E–20m*(200x150km),90°rake,13°dip,300°strike,5m depth)+
(7.3559°N,94.1393°E–20m*(670x150km),90°rake,13°dip,345°strike,5m depth)+(11.605°N,93.4723°E–20m*(300x150km),90°rake,13°dip,365°strike,5m depth)



Natural Warning Signs

A strong earthquake felt in a low-lying coastal area is a natural warning of immediate danger. Keep calm and quickly move to higher ground away from the coast.



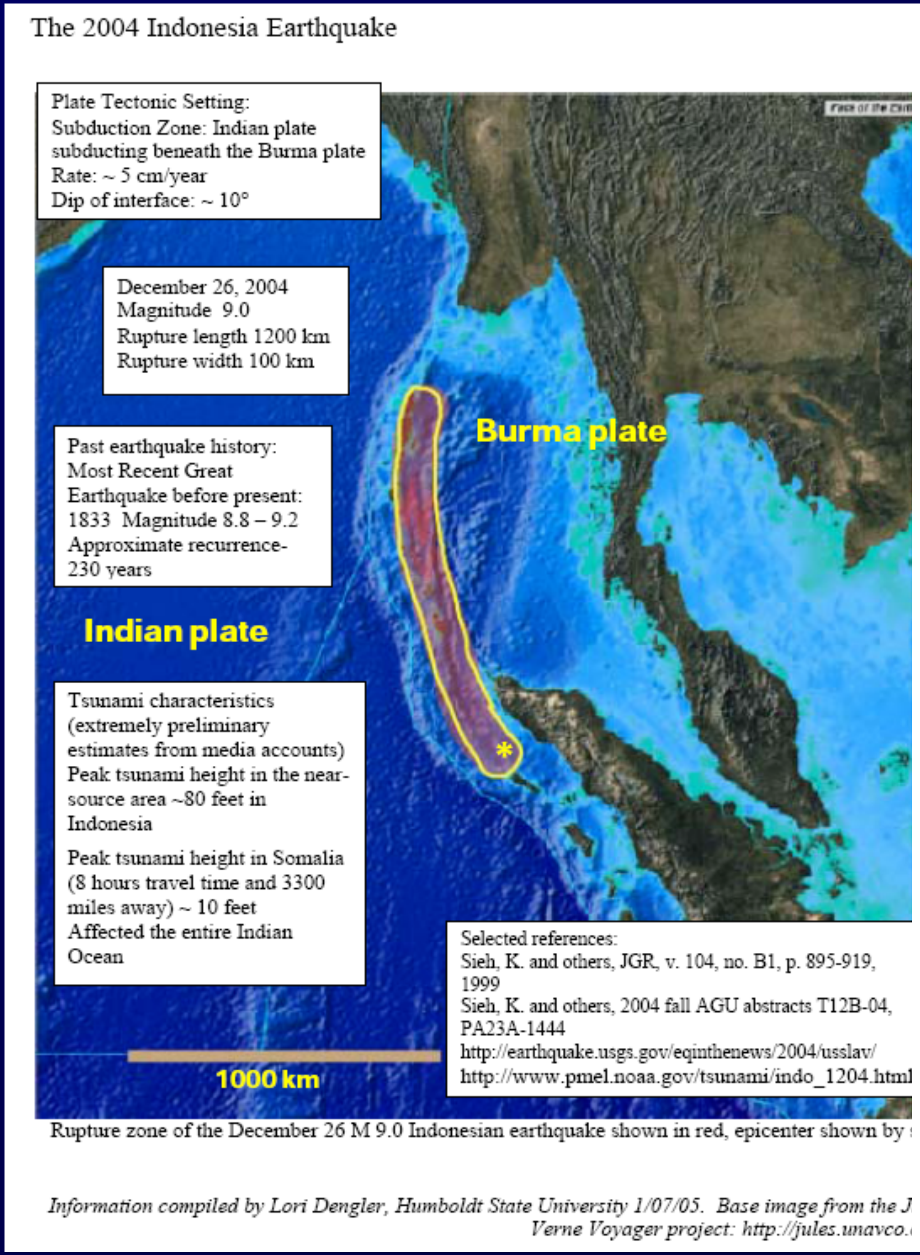
Approaching tsunamis are sometimes heralded by noticeable rise or fall of coastal waters. This is nature's tsunami warning and should be heeded.

Tsunami Tips

Approaching large tsunamis are usually accompanied by a loud roar that sounds like a train or aircraft. If a tsunami arrives at night when you cannot see the ocean, this is also nature's tsunami warning and should be heeded.

Never go down to the beach to watch for a tsunami! WHEN YOU CAN SEE THE WAVE, YOU ARE TOO CLOSE TO ESCAPE! Tsunamis can move faster than a person can run.

Subduction Zone Comparison



The 2004 Indonesia Earthquake

Plate Tectonic Setting:
Subduction Zone: Indian plate subducting beneath the Burma plate
Rate: ~ 5 cm/year
Dip of interface: ~ 10°

December 26, 2004
Magnitude 9.0
Rupture length 1200 km
Rupture width 100 km

Past earthquake history:
Most Recent Great Earthquake before present:
1833 Magnitude 8.8 – 9.2
Approximate recurrence- 230 years

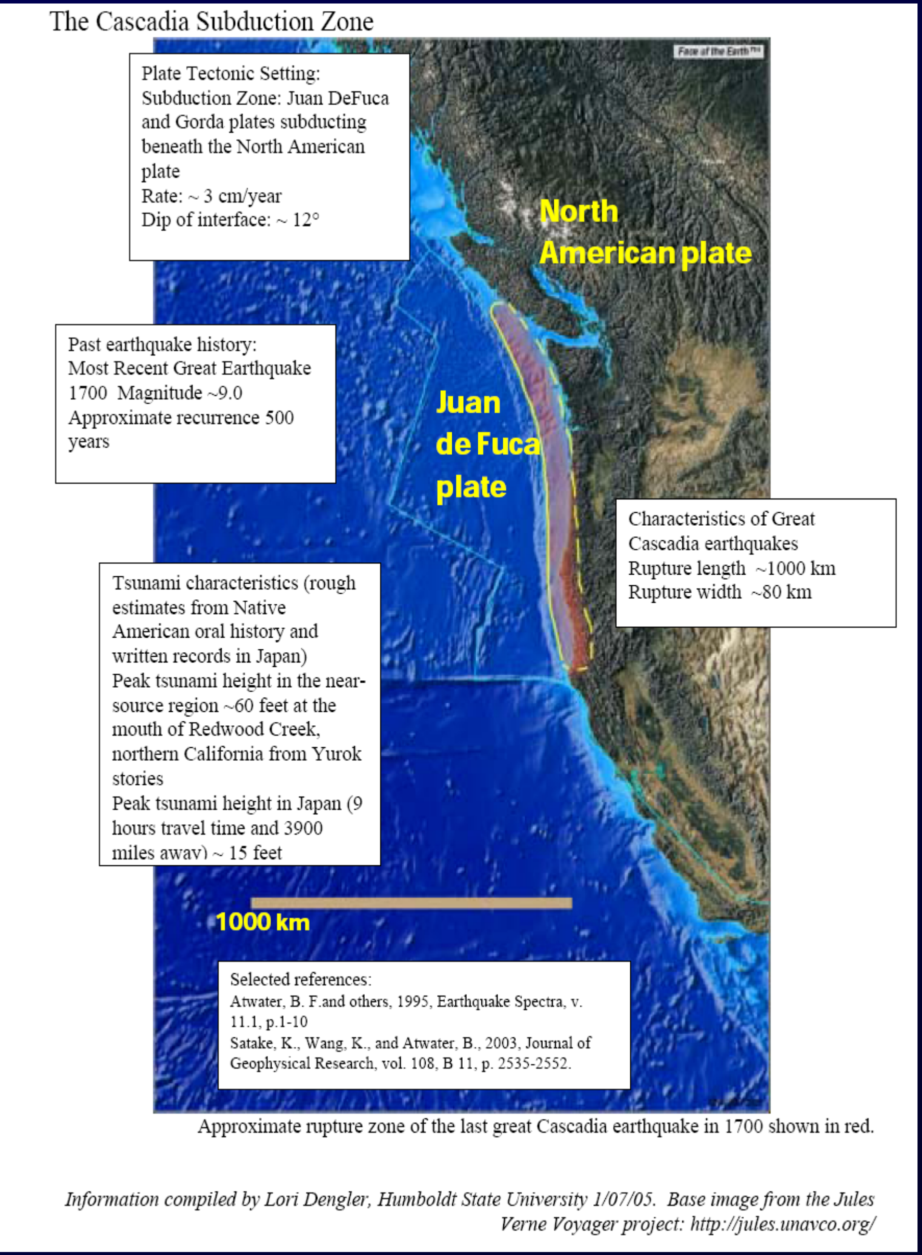
Tsunami characteristics (extremely preliminary estimates from media accounts)
Peak tsunami height in the near-source area ~80 feet in Indonesia

Peak tsunami height in Somalia (8 hours travel time and 3300 miles away) ~ 10 feet
Affected the entire Indian Ocean

Selected references:
Sieh, K. and others, JGR, v. 104, no. B1, p. 895-919, 1999
Sieh, K. and others, 2004 fall AGU abstracts T12B-04, PA23A-1444
http://earthquake.usgs.gov/eqinthenews/2004/usslav/
http://www.pmel.noaa.gov/tsunami/indo_1204.html

Rupture zone of the December 26 M 9.0 Indonesian earthquake shown in red, epicenter shown by

Information compiled by Lori Dengler, Humboldt State University 1/07/05. Base image from the J
Verne Voyager project: http://jules.unavco.



The Cascadia Subduction Zone

Plate Tectonic Setting:
Subduction Zone: Juan DeFuca and Gorda plates subducting beneath the North American plate
Rate: ~ 3 cm/year
Dip of interface: ~ 12°

Past earthquake history:
Most Recent Great Earthquake
1700 Magnitude ~9.0
Approximate recurrence 500 years

Characteristics of Great Cascadia earthquakes
Rupture length ~1000 km
Rupture width ~80 km

Tsunami characteristics (rough estimates from Native American oral history and written records in Japan)
Peak tsunami height in the near-source region ~60 feet at the mouth of Redwood Creek, northern California from Yurok stories
Peak tsunami height in Japan (9 hours travel time and 3900 miles away) ~ 15 feet

Selected references:
Atwater, B. F.and others, 1995, Earthquake Spectra, v. 11.1, p.1-10
Satake, K., Wang, K., and Atwater, B., 2003, Journal of Geophysical Research, vol. 108, B 11, p. 2535-2552.

Approximate rupture zone of the last great Cascadia earthquake in 1700 shown in red.

Information compiled by Lori Dengler, Humboldt State University 1/07/05. Base image from the Jules
Verne Voyager project: http://jules.unavco.org/

Threat Assessment Local Events

Earthquakes

Landslides

Threat Assessment Distance Event

Tsunamis on average occur in the Pacific basin about six every 100 years

House torn apart at Pacific Beach

Highway 109 bridge over Copalis River

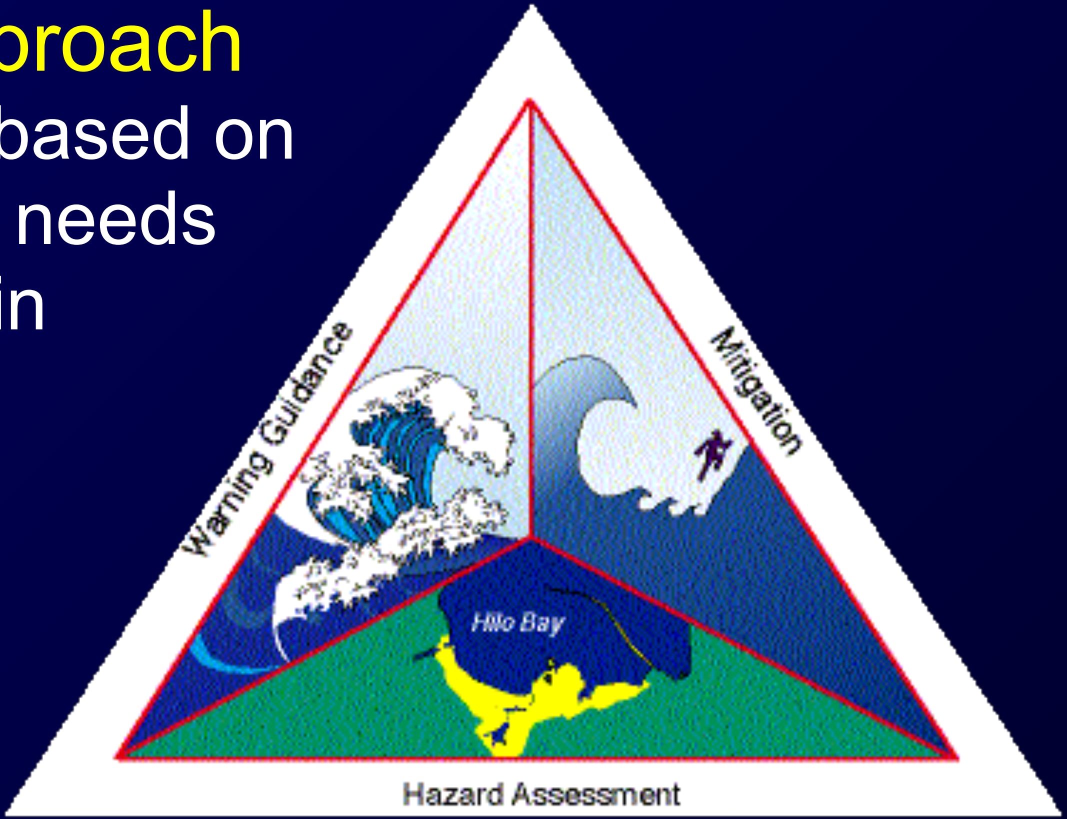
1964 Good Friday Tsunami on the Washington coast

– 9.2 Magnitude Alaskan Earthquake

State/Local Tsunami Workgroup

Bottom up approach

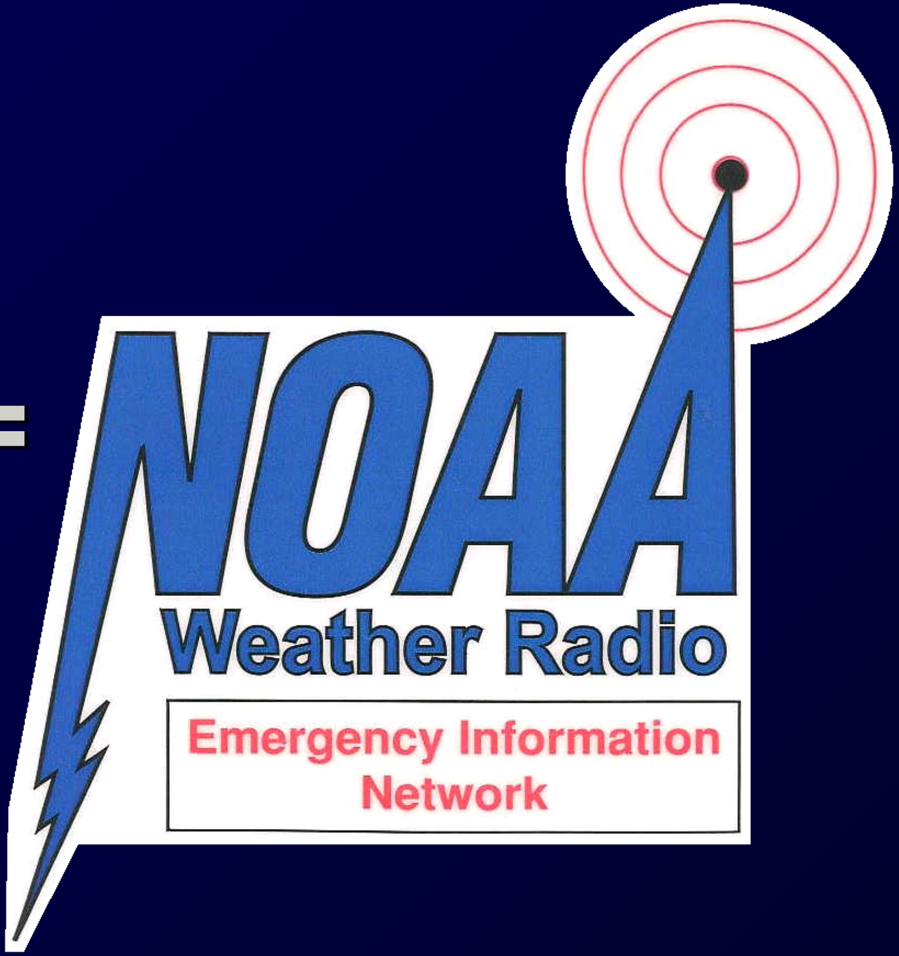
- Strategies based on community needs
- Rapid buy in



"Defining clear goals and objectives is one of the most important -- Initial activities provides a platform for an effective risk communication"

Integrated on-shore communications infrastructure

=

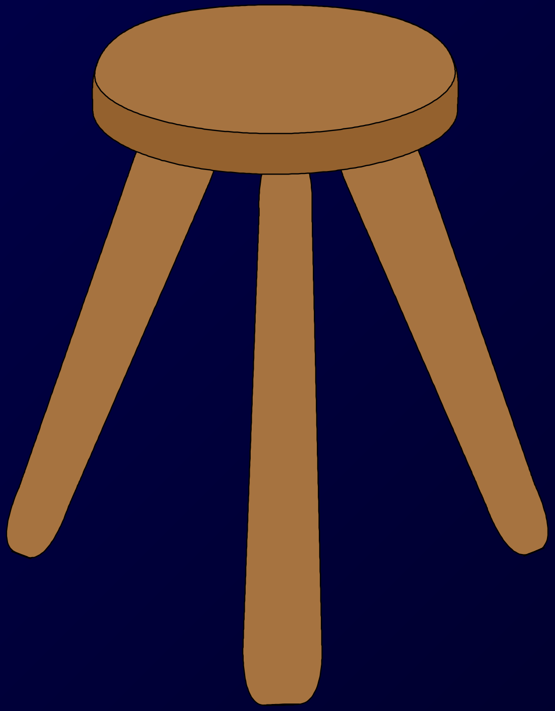


The Warning System

- Detection / Warning

- Dissemination

- Response



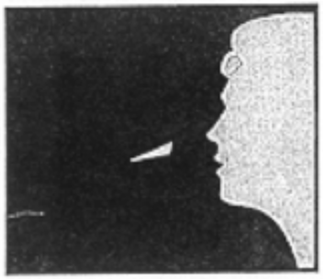
Warning System Goal:

To maximize the number of people who take appropriate and timely action to minimize injury, death, and property damage due to hazardous weather and flooding.

Social Science – How People Respond to Warning Messages

Public Response

- Receive
- Understand
- Believe
- Personalize
- Decide to Act



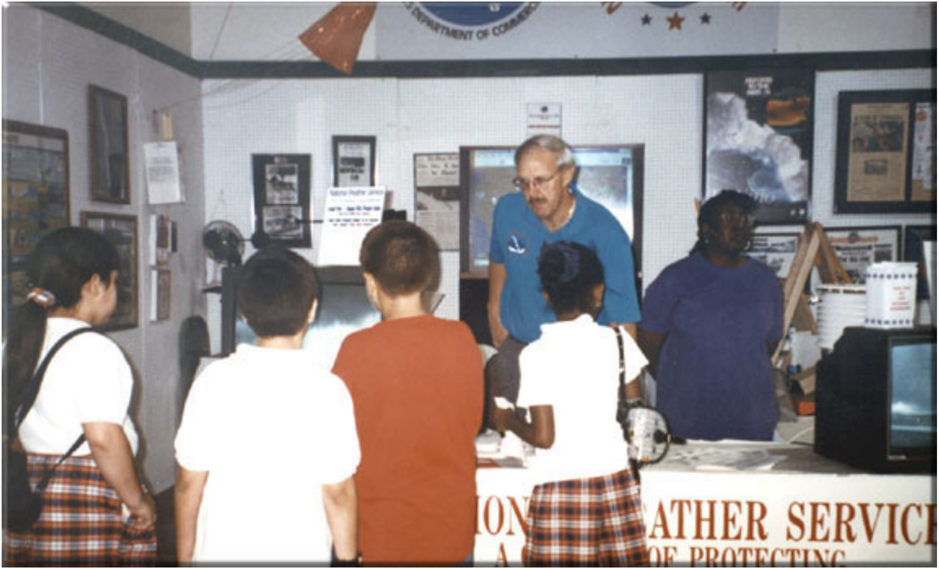
National Weather Service Mission

Provide Weather, Hydrologic, and Climate Forecasts and Warnings for the United States, its Territories, Adjacent Waters and Ocean Areas, for the Protection of Life and Property and Enhancement of the National Economy.

Who We Are

National Weather Forecast Office (WFO) Team: Community Weather Experts

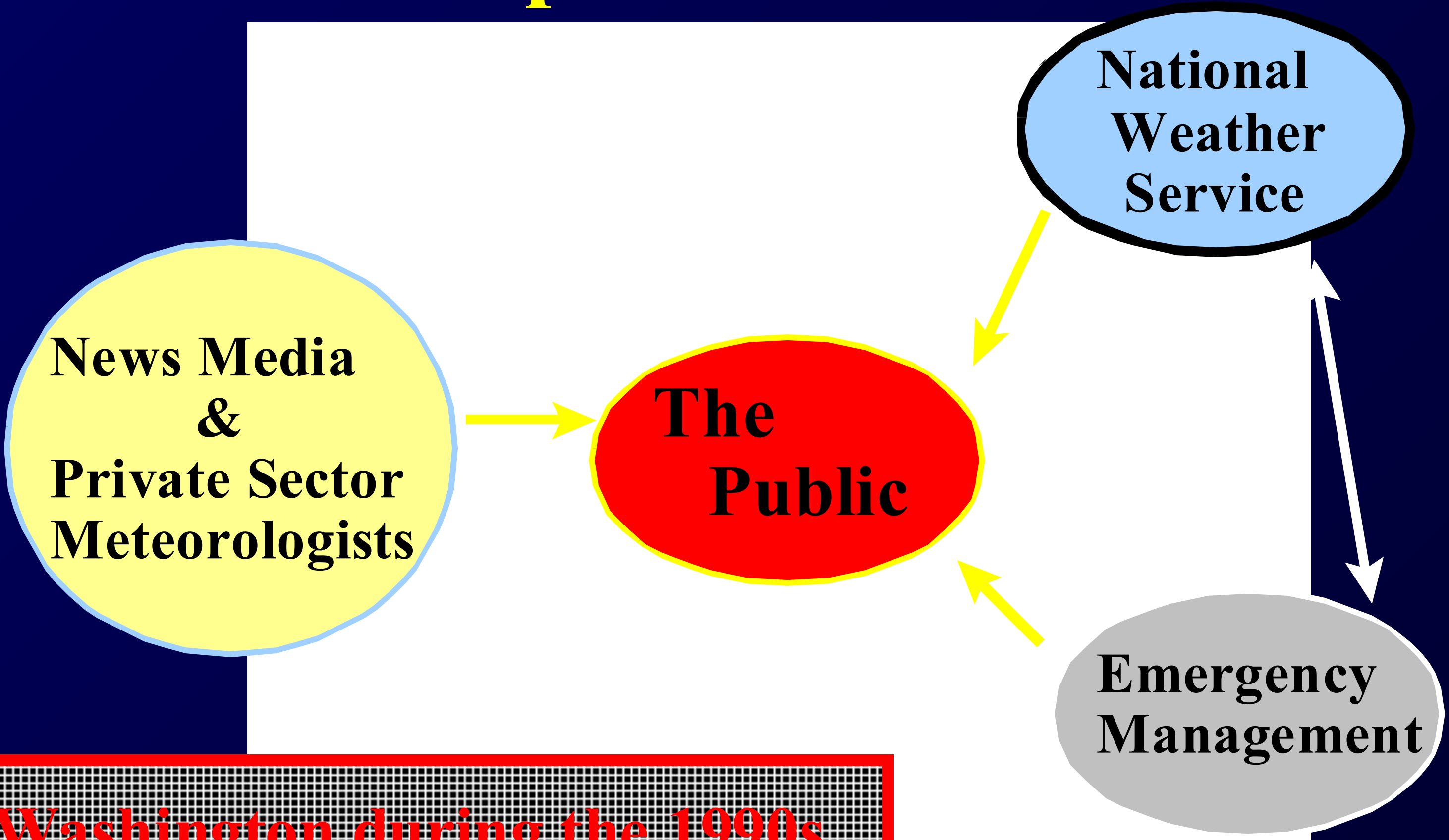
- Issues all Local Forecasts & Warnings
- Builds and Maintains Relationships With Local and State Governments
- Provides Expert Advice to Emergency Operations Centers
- Solicits Customer Feedback on Products and Services
- Conducts Community Awareness and Education Progran
- Trains Volunteer Observers and Storm Spotters



Washington's Non-Weather Hazards (NWS Support)

- Tsunami
- Volcanic
- HazMat
- Search and Rescue
- Earthquake
- Dam Break

The Weather Warning Partnership:



National Weather Service

News Media & Private Sector Meteorologists

The Public

Emergency Management

In Washington during the 1990s

- Nearly 100 Fatalities,
- Hundreds Injured,
- Over $1 Billion in Property Damage

WFO Seattle

Media Partners

seattletimes.com
The Seattle Times

NBCi

The Olympian
SERVING WASHINGTON'S SOUTH PUGET SOUND

abc

710 KIRO NEWSRADIO

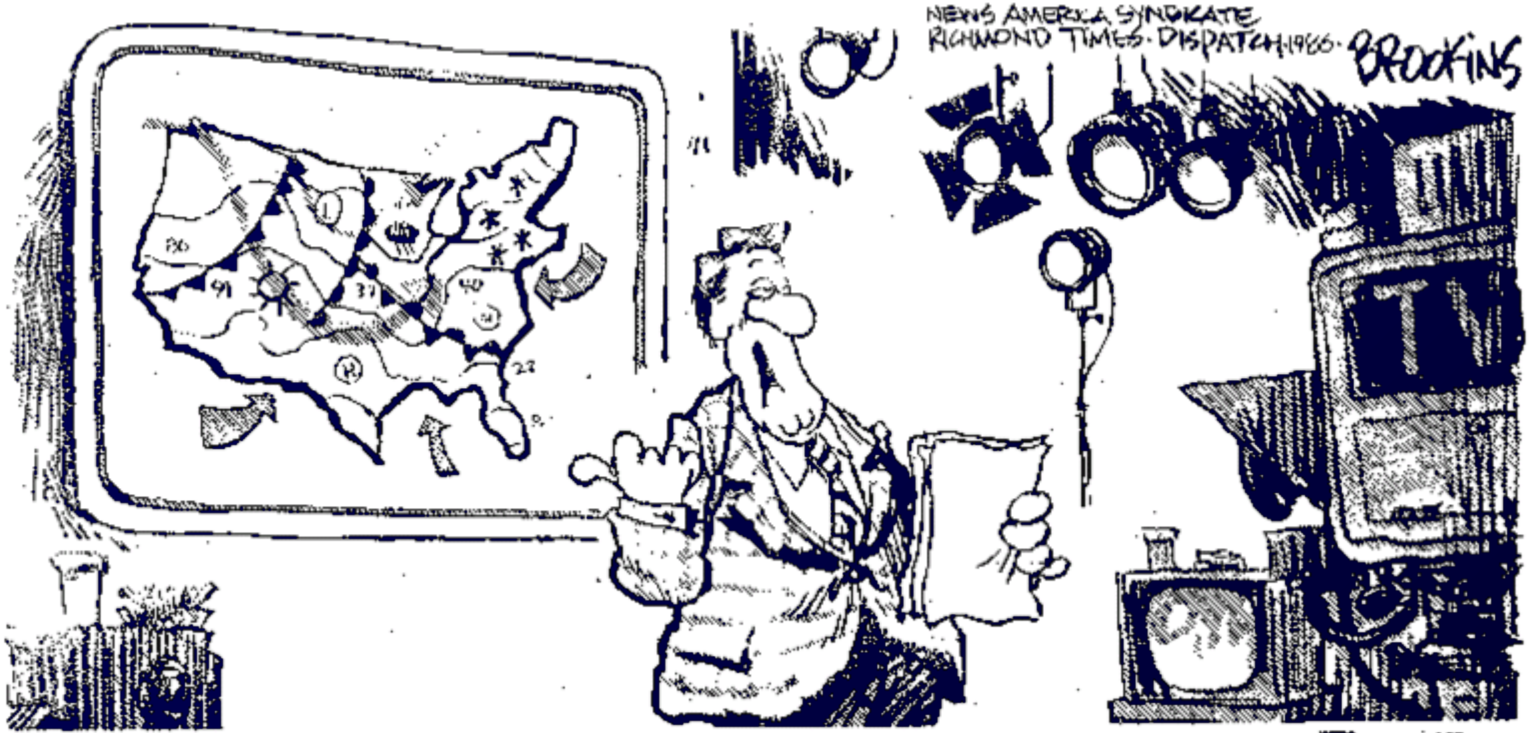
KOMO 1000 News
Home of the Mariners

cbs.com

FOX NEWS channel

seattle P-I.com

How Do You Get Your Weather Information Today?


NEWS AMERICA SYNDICATE
RICHMOND TIMES-DISPATCH 1986 · BROOKINS

"...THERE IS AN 80% CHANCE THAT I HAVE NO IDEA WHAT THE WEATHER WILL BE TOMORROW!"

Have You Ever Turned From One Station To Another and Heard a Different Forecast ?

Warning Systems – Passive vs Active

Passive

- The Internet
- Commercial Radio
- Television / Cable
- Newspaper

Active

- Emergency Managers Weather Information Network (EMWIN)
- NOAA Weather Radio (NWR)
- Emergency Alert System (EAS)

NOAA Weather Radio (NWR) Emergency Information Network

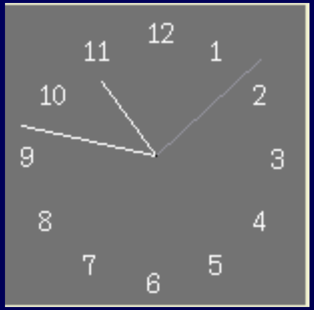
- Tsunami Warning System
  - ✓ Ineffective if it doesn't reach each of us where ever we are
  - ✓ One system fits all
- Hardens each community's communications infrastructure
- Rapid and reliable communications
- Utilization of NWR and All Hazard Alert Broadcasting (AHAB) Radio
  - ✓ Designated critical facilities
  - ✓ Businesses, hospitals, residents
  - ✓ High trafficked areas

NOAA
Weather Radio
Emergency Information Network

NOAA Weather Radio

A Life Saver for the Cost of a Pair of Shoes

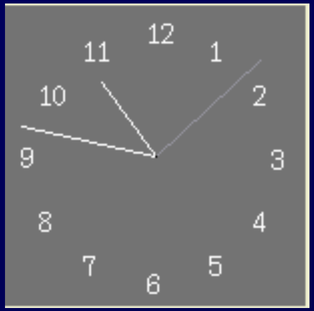
Direct from the NWS 24 hours a day



NOAA Weather Radio

A Life Saver for the Cost of a Pair of Shoes

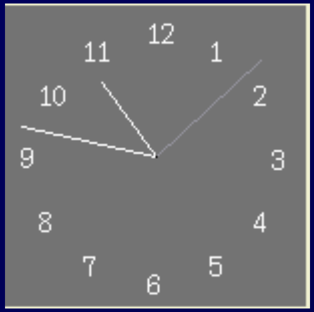
Latest Area Forecasts and Conditions

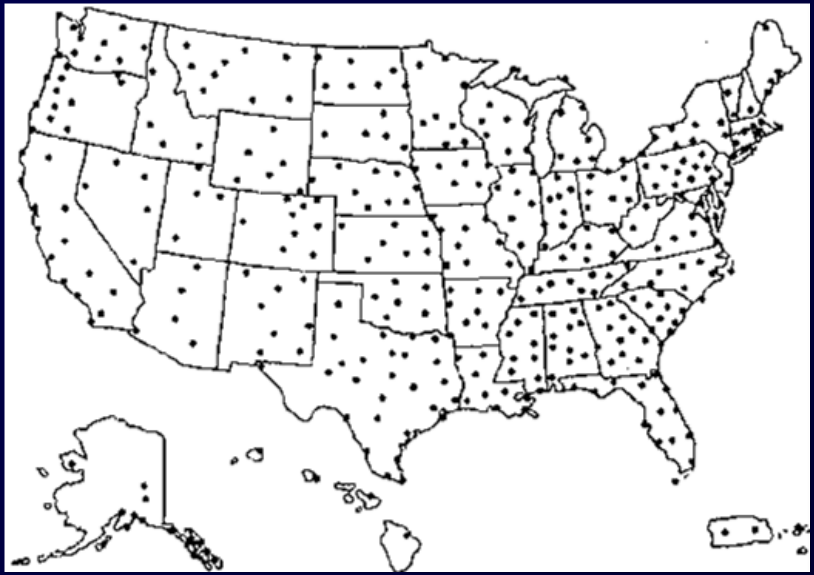


NOAA Weather Radio

A Life Saver for the Cost of a Pair of Shoes

Over 900 Stations Across the Nation

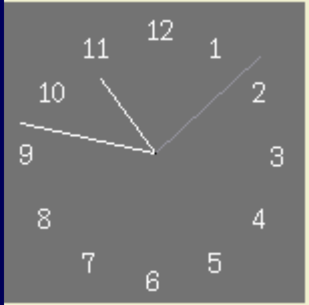


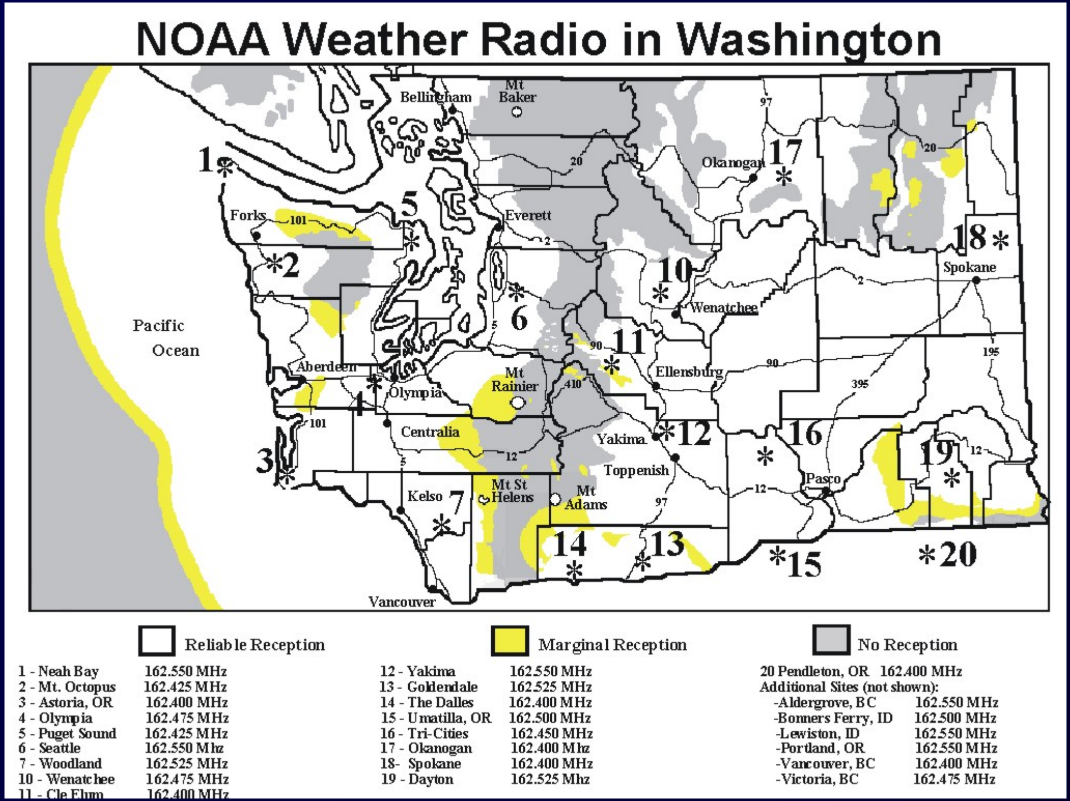


NOAA Weather Radio

A Life Saver for the Cost of a Pair of Shoes

21 Stations Serving Washington





NOAA Weather Radio in Washington

☐ Reliable Reception

🟨 Marginal Reception

▨ No Reception

1 - Neah Bay	162.550 MHz
2 - Mt. Octopus	162.425 MHz
3 - Astoria, OR	162.400 MHz
4 - Olympia	162.475 MHz
5 - Puget Sound	162.425 MHz
6 - Seattle	162.550 Mhz
7 - Woodland	162.525 MHz
10 - Wenatchee	162.475 MHz
11 - Cle Elum	162.400 MHz

12 - Yakima	162.550 MHz
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14 - The Dalles	162.400 MHz
15 - Umatilla, OR	162.500 MHz
16 - Tri-Cities	162.450 MHz
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18- Spokane	162.400 MHz
19 - Dayton	162.525 Mhz

20 Pendleton, OR 162.400 MHz

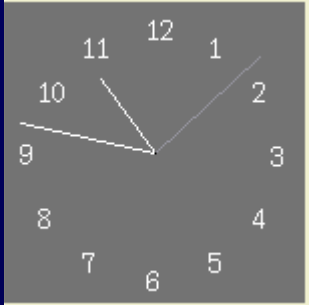
Additional Sites (not shown):

-Aldergrove, BC	162.550 MHz
-Bonners Ferry, ID	162.500 MHz
-Lewiston, ID	162.550 MHz
-Portland, OR	162.550 MHz
-Vancouver, BC	162.400 MHz
-Victoria, BC	162.475 MHz

NOAA Weather Radio

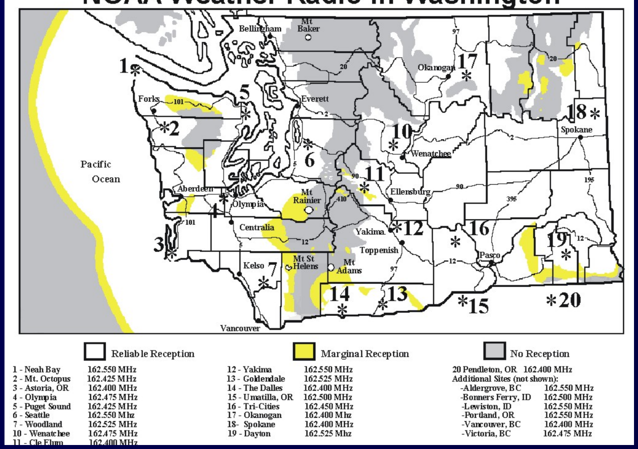
A Life Saver for the Cost of a Pair of Shoes

Has a Warning Alarm Feature



IMPORTANT: SEE OWNERS MANUAL FOR COMPLETE OPERATING INSTRUCTIONS
PUSH AND HOLD
TO TEST WEEKLY
OFF TWIST ON

NOAA Weather Radio in Washington


Bellingham
Mt Baker
Okanogan
Forks
Everett
Spokane
Wenatchee
Pacific Ocean
Aberdeen
Olympia
Mt Rainier
Ellensburg
Centralia
Yakima
Toppenish
Pasco
Kelso
Mt St Helens
Mt Adams
Vancouver
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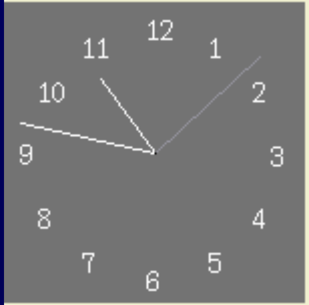
NOAA Weather Radio

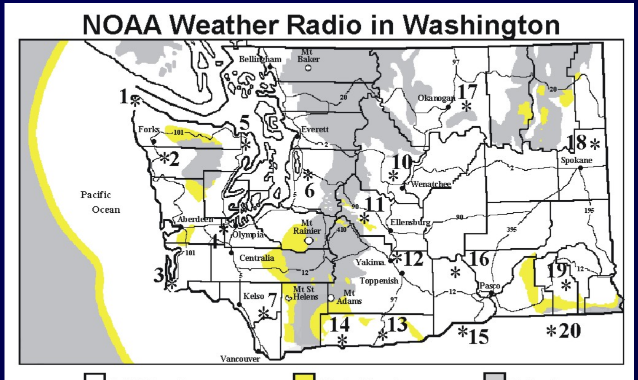
A Life Saver for the Cost of a Pair of Shoes

Flood and Weather Warnings as Needed



SKYWARN

NOAA Weather Radio in Washington



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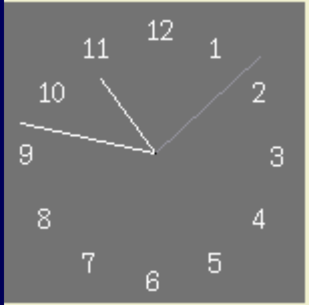
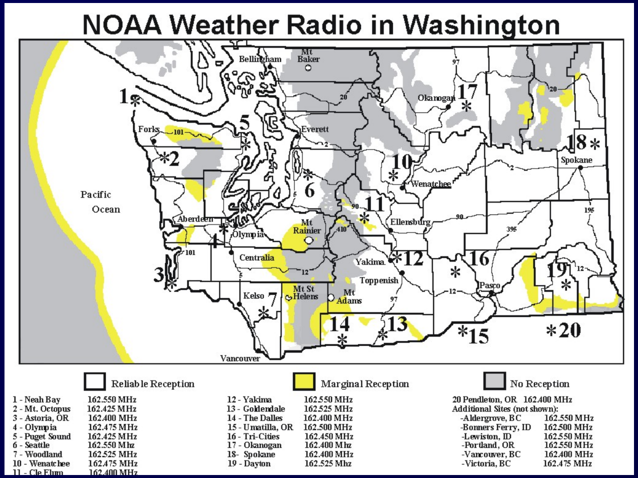
NOAA Weather Radio

A Life Saver for the Cost of a Pair of Shoes

- Key Element in Emergency Alert System (EAS)





NOAA Weather Radio in Washington

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NOAA Weather Radio

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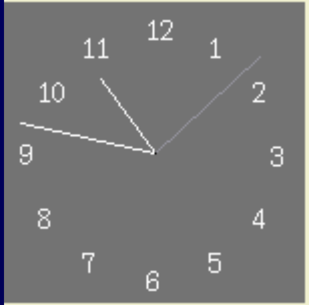
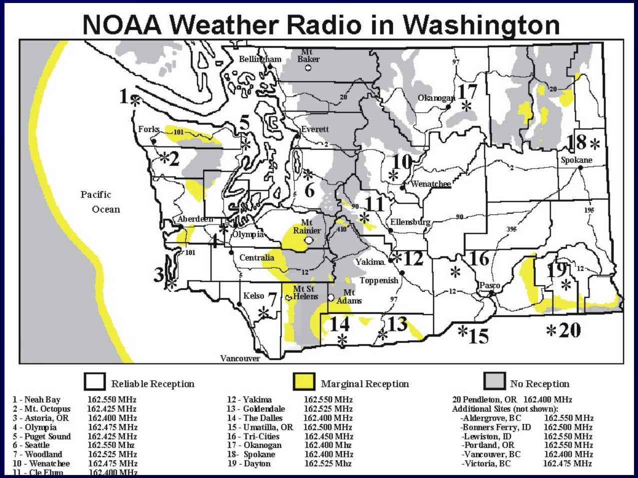
NOAA Weather Radio

"All-Hazards" Warning System





NOAA Weather Radio in Washington

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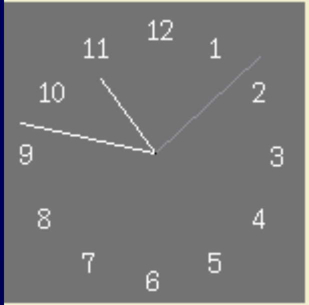
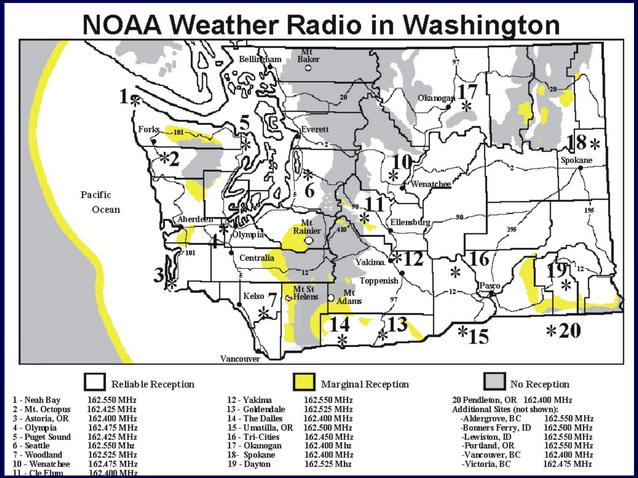
EAS

NOAA Weather Radio

A Life Saver for the Cost of a Pair of Shoes

Receivers Available at Most Radio Electronic Retailers and via the Internet





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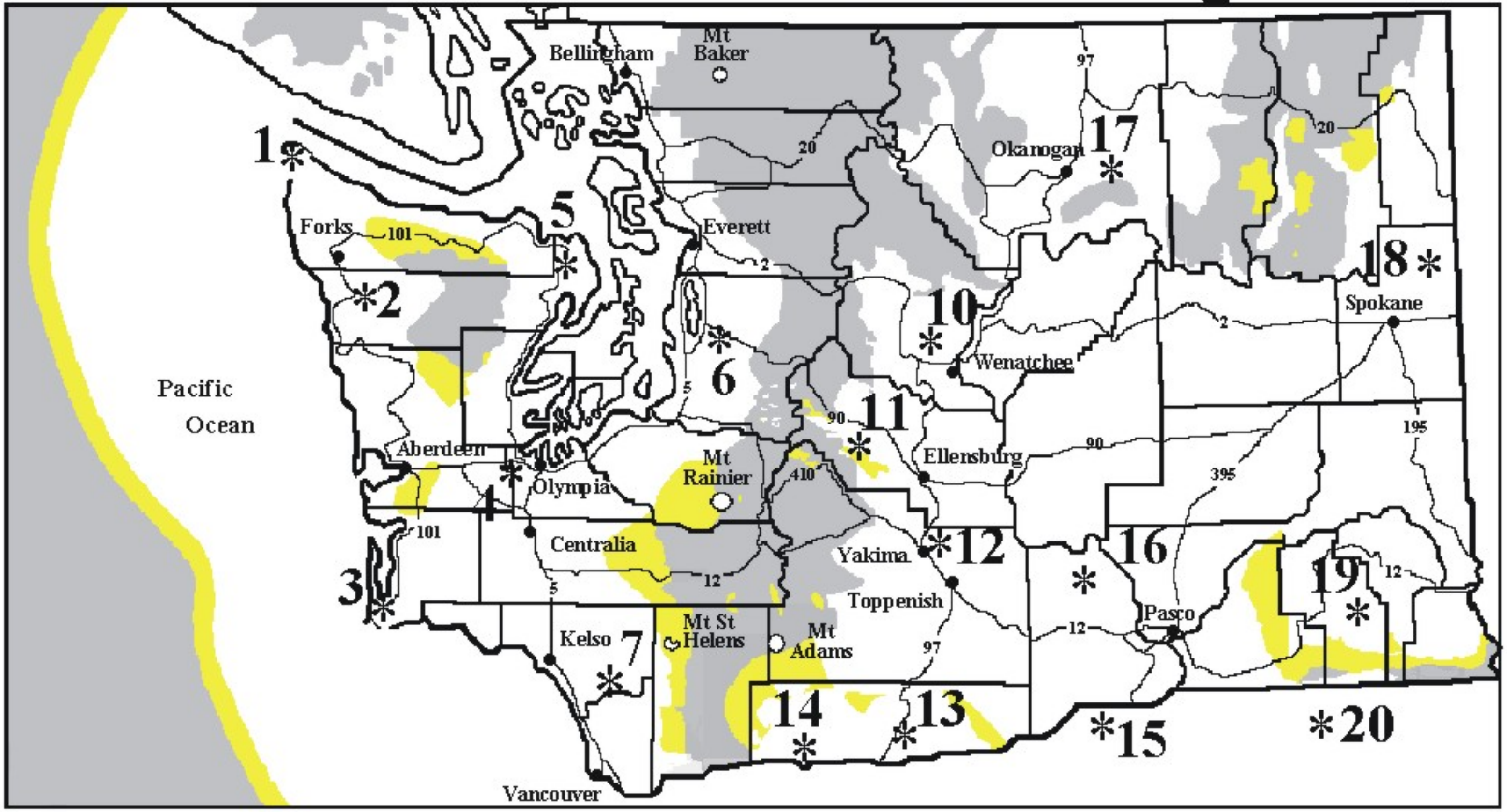
SKYWARN

EAS

Today

NOAA Weather Radio in Washington



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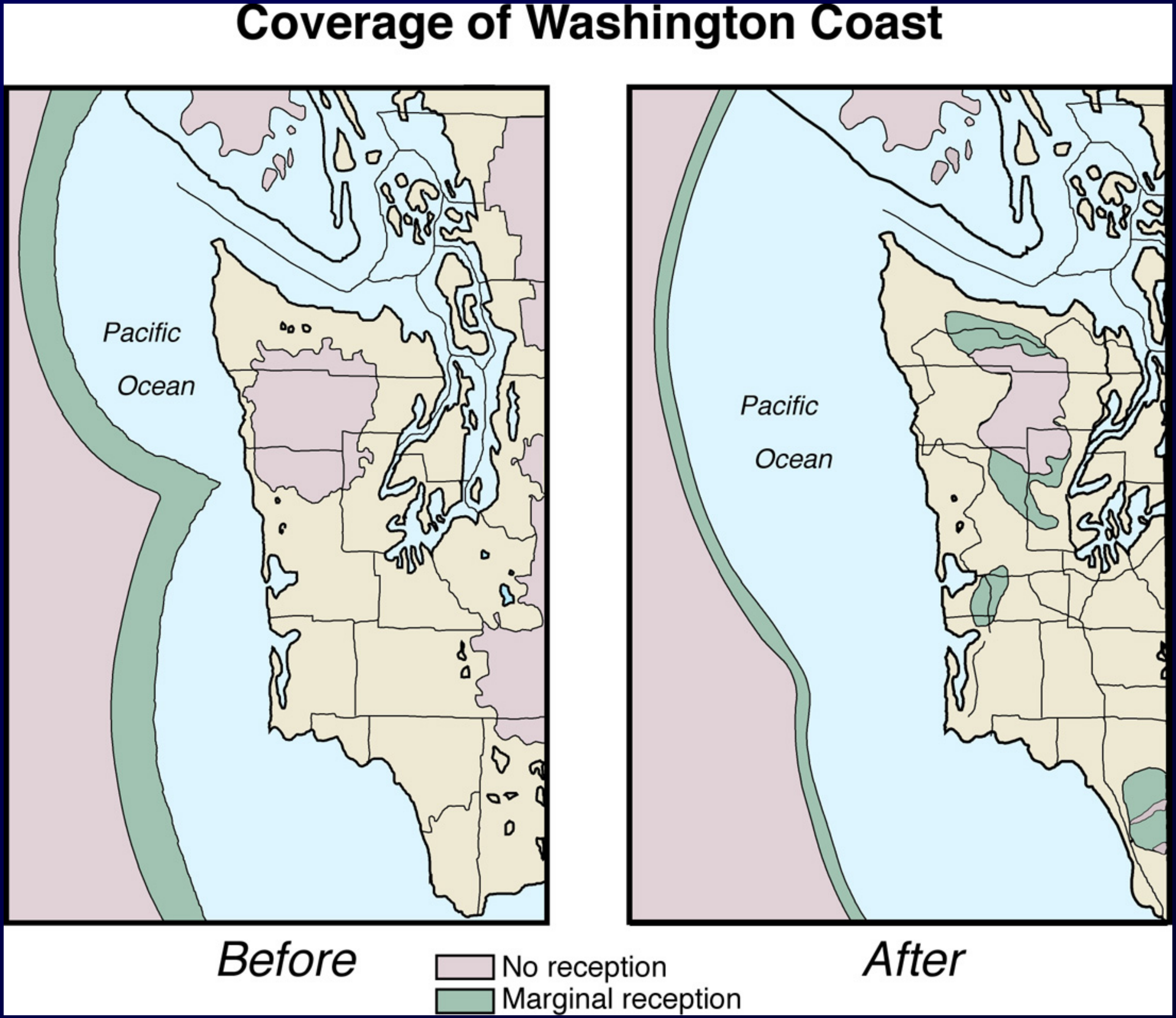
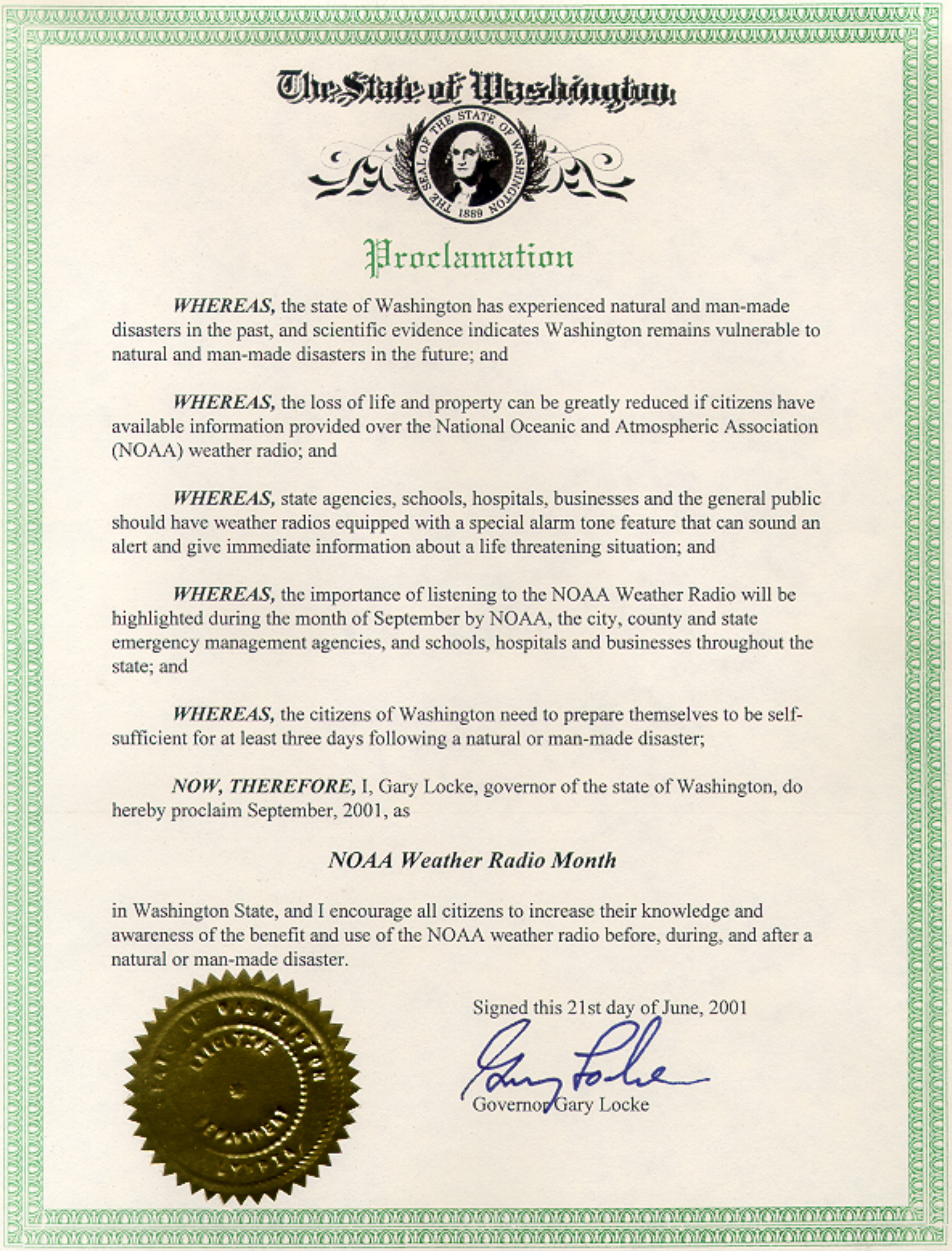
-Vancouver, BC	162.400 MHz
-Victoria, BC	162.475 MHz

Mount Octopus NOAA Weather Radio Transmitter Site Project



NOAA Weather Radio is Washington's "All-Hazards" Warning System



The State of Washington

1889

Proclamation

WHEREAS, the state of Washington has experienced natural and man-made disasters in the past, and scientific evidence indicates Washington remains vulnerable to natural and man-made disasters in the future; and

WHEREAS, the loss of life and property can be greatly reduced if citizens have available information provided over the National Oceanic and Atmospheric Association (NOAA) weather radio; and

WHEREAS, state agencies, schools, hospitals, businesses and the general public should have weather radios equipped with a special alarm tone feature that can sound an alert and give immediate information about a life threatening situation; and

WHEREAS, the importance of listening to the NOAA Weather Radio will be highlighted during the month of September by NOAA, the city, county and state emergency management agencies, and schools, hospitals and businesses throughout the state; and

WHEREAS, the citizens of Washington need to prepare themselves to be self-sufficient for at least three days following a natural or man-made disaster;

NOW, THEREFORE, I, Gary Locke, governor of the state of Washington, do hereby proclaim September, 2001, as

NOAA Weather Radio Month

in Washington State, and I encourage all citizens to increase their knowledge and awareness of the benefit and use of the NOAA weather radio before, during, and after a natural or man-made disaster.

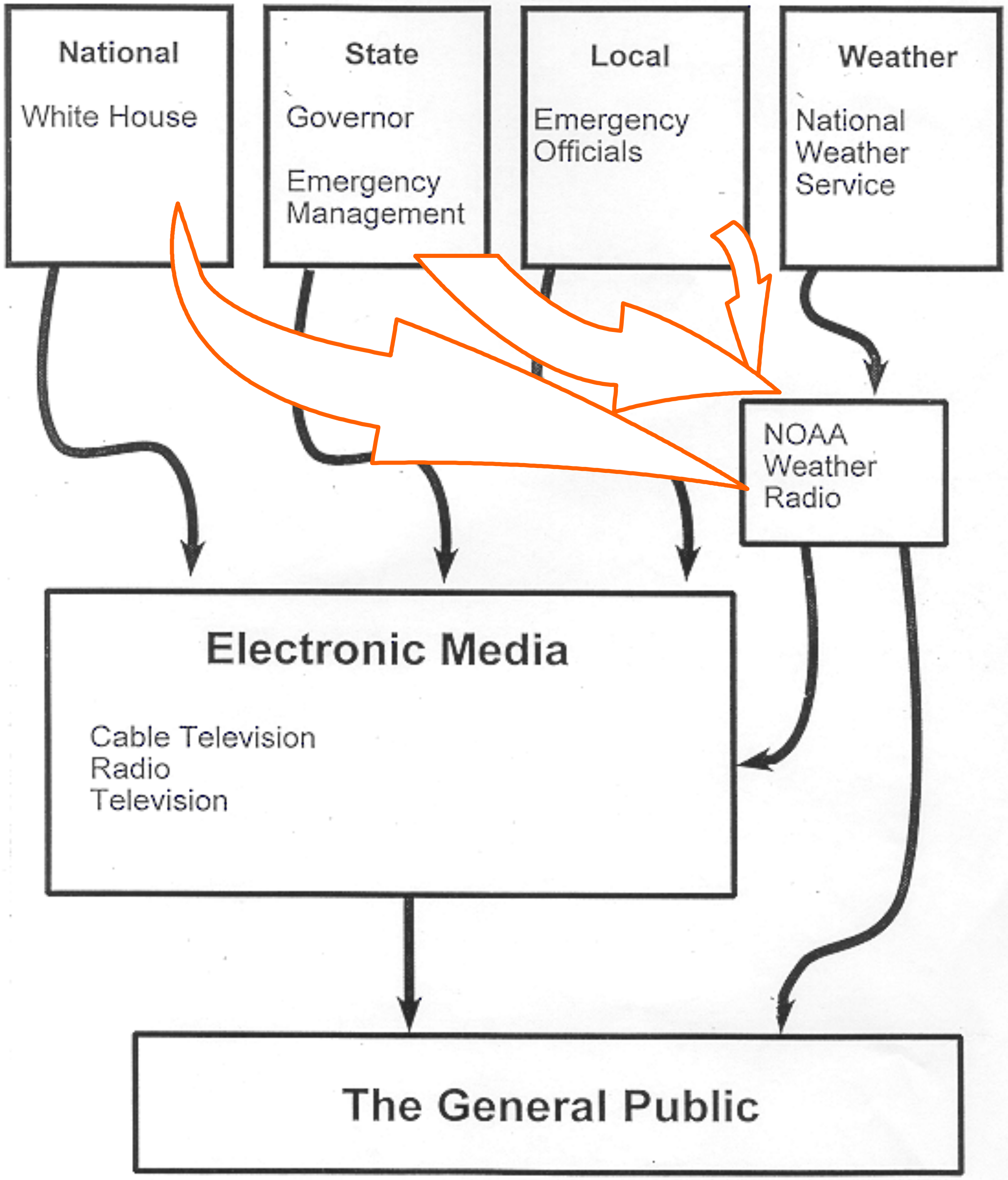
Signed this 21st day of June, 2001

Gary Locke

Governor Gary Locke

Ocean Shores "AHAB"

EAS Message Originating Sources



National
White House

State
Governor
Emergency Management

Local
Emergency Officials

Weather
National Weather Service

NOAA Weather Radio

Electronic Media
Cable Television
Radio
Television

The General Public

NWS Messages to EAS

* Tornado Watch or Warning

* Severe Thunderstorm Watch or Warning

* Flash Flood Watch or Warning

* Flood Warning

* High Wind Warning

* Winter Storm / Heavy Snow / Blizzard Warning

* Tsunami Watch or Warning

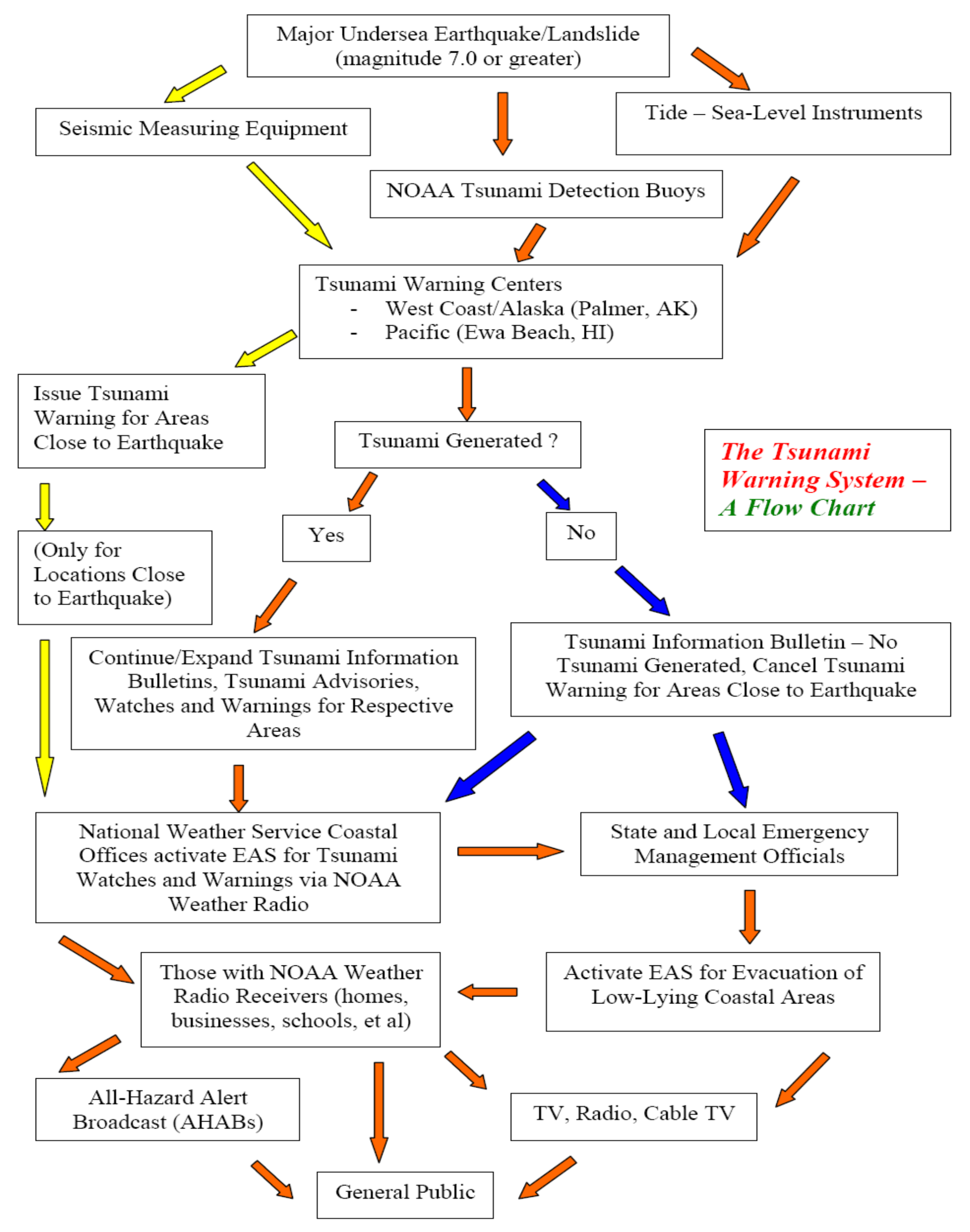
* Civil Emergency Message

Non -NWS Messages on NOAA Weather Radio

Examples include:

- Civil Emergency Warning
- Evacuation Immediate
- Volcano Warning
- Shelter in Place Warning
- Child Abduction Emergency (AMBER)

The Tsunami Warning System


Major Undersea Earthquake/Landslide (magnitude 7.0 or greater)

Seismic Measuring Equipment

NOAA Tsunami Detection Buoys

Tide – Sea-Level Instruments

Tsunami Warning Centers
- West Coast/Alaska (Palmer, AK)
- Pacific (Ewa Beach, HI)

Issue Tsunami Warning for Areas Close to Earthquake

(Only for Locations Close to Earthquake)

Tsunami Generated ?

Yes

No

The Tsunami Warning System – A Flow Chart

Continue/Expand Tsunami Information Bulletins, Tsunami Advisories, Watches and Warnings for Respective Areas

Tsunami Information Bulletin – No Tsunami Generated, Cancel Tsunami Warning for Areas Close to Earthquake

National Weather Service Coastal Offices activate EAS for Tsunami Watches and Warnings via NOAA Weather Radio

State and Local Emergency Management Officials

Those with NOAA Weather Radio Receivers (homes, businesses, schools, et al)

Activate EAS for Evacuation of Low-Lying Coastal Areas

All-Hazard Alert Broadcast (AHABs)

TV, Radio, Cable TV

General Public

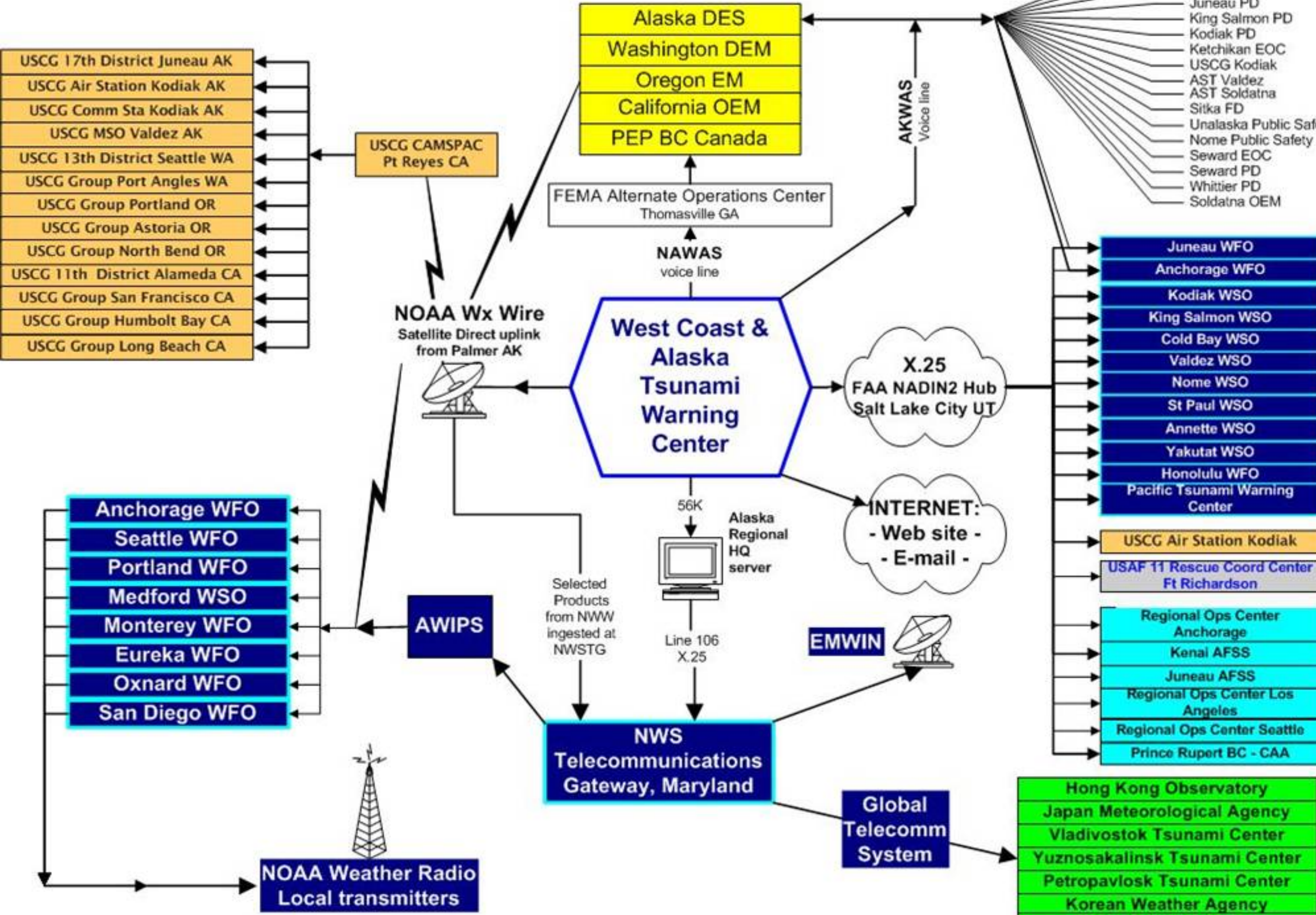
NOAA Tsunami “DART” Buoy

Tsunami Warning Center – Palmer, Alaska

Weather Radio Receiver

West Coast & Alaska Tsunami Warning Center

Communications Links



West Coast & Alaska Tsunami Warning Center

Alaska DES
Washington DEM
Oregon EM
California OEM
PEP BC Canada

FEMA Alternate Operations Center
Thomasville GA

NAWAS
voice line

AKWAS
Voice line

Cordova PD
Dillingham PD
Homer PD
Juneau PD
King Salmon PD
Kodiak PD
Ketchikan EOC
USCG Kodiak
AST Valdez
AST Soldatna
Sitka FD
Unalaska Public Saf
Nome Public Safety
Seward EOC
Seward PD
Whittier PD
Soldatna OEM

USCG 17th District Juneau AK
USCG Air Station Kodiak AK
USCG Comm Sta Kodiak AK
USCG MSO Valdez AK
USCG 13th District Seattle WA
USCG Group Port Angles WA
USCG Group Portland OR
USCG Group Astoria OR
USCG Group North Bend OR
USCG 11th District Alameda CA
USCG Group San Francisco CA
USCG Group Humbolt Bay CA
USCG Group Long Beach CA

USCG CAMSPAC
Pt Reyes CA

NOAA Wx Wire
Satellite Direct uplink
from Palmer AK

X.25
FAA NADIN2 Hub
Salt Lake City UT

Juneau WFO
Anchorage WFO
Kodiak WSO
King Salmon WSO
Cold Bay WSO
Valdez WSO
Nome WSO
St Paul WSO
Annette WSO
Yakutat WSO
Honolulu WFO
Pacific Tsunami Warning Center

USCG Air Station Kodiak

USAF 11 Rescue Coord Center
Ft Richardson

Regional Ops Center Anchorage
Kenai AFSS
Juneau AFSS
Regional Ops Center Los Angeles
Regional Ops Center Seattle
Prince Rupert BC - CAA

INTERNET:
- Web site -
- E-mail -

56K

Alaska Regional HQ server

Line 106
X.25

Selected Products from NWW ingested at NWSTG

EMWIN

AWIPS

Anchorage WFO
Seattle WFO
Portland WFO
Medford WSO
Monterey WFO
Eureka WFO
Oxnard WFO
San Diego WFO

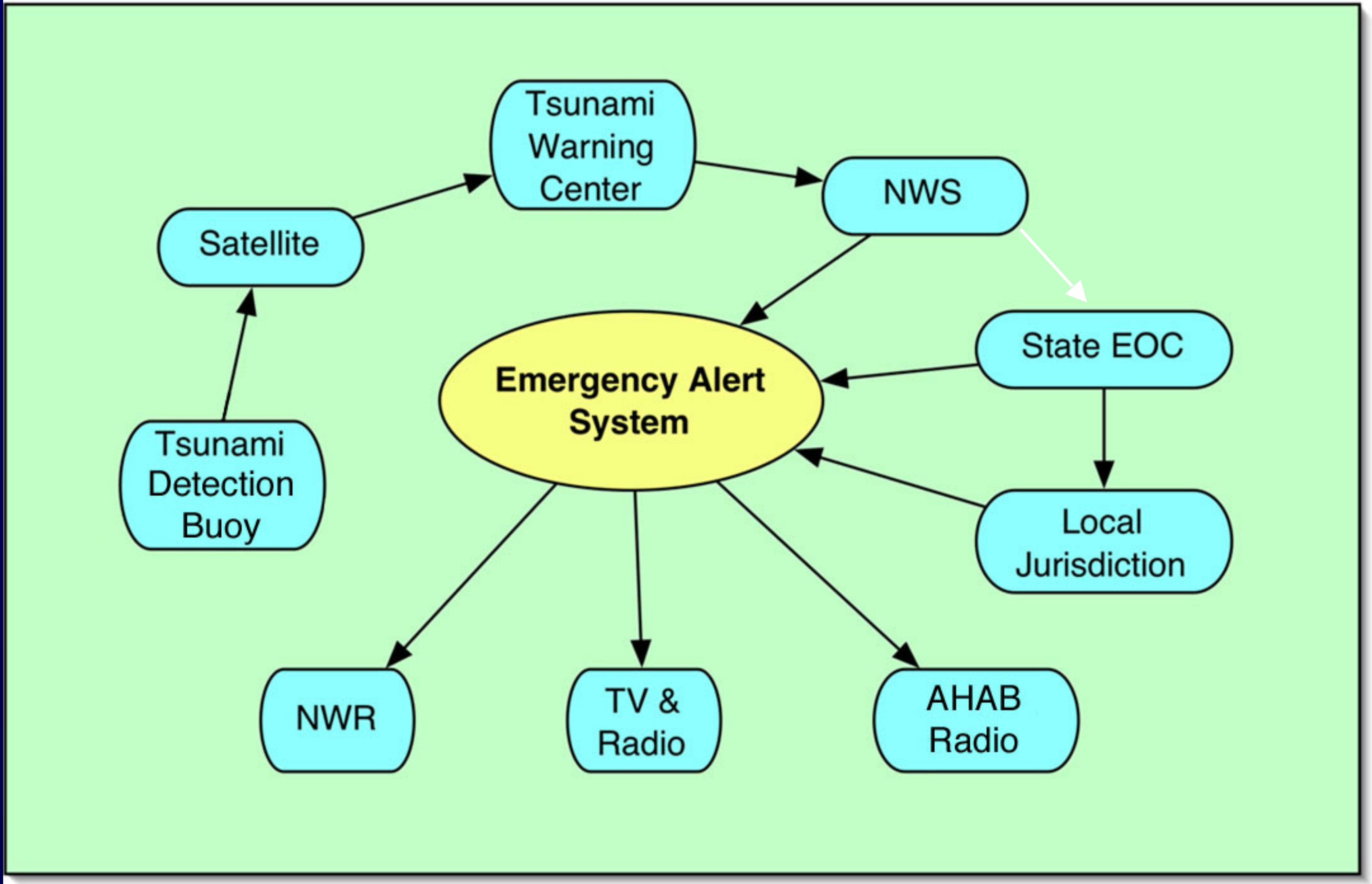
NWS Telecommunications Gateway, Maryland

Global Telecomm System

Hong Kong Observatory
Japan Meteorological Agency
Vladivostok Tsunami Center
Yuznosakalinsk Tsunami Center
Petropavlosk Tsunami Center
Korean Weather Agency

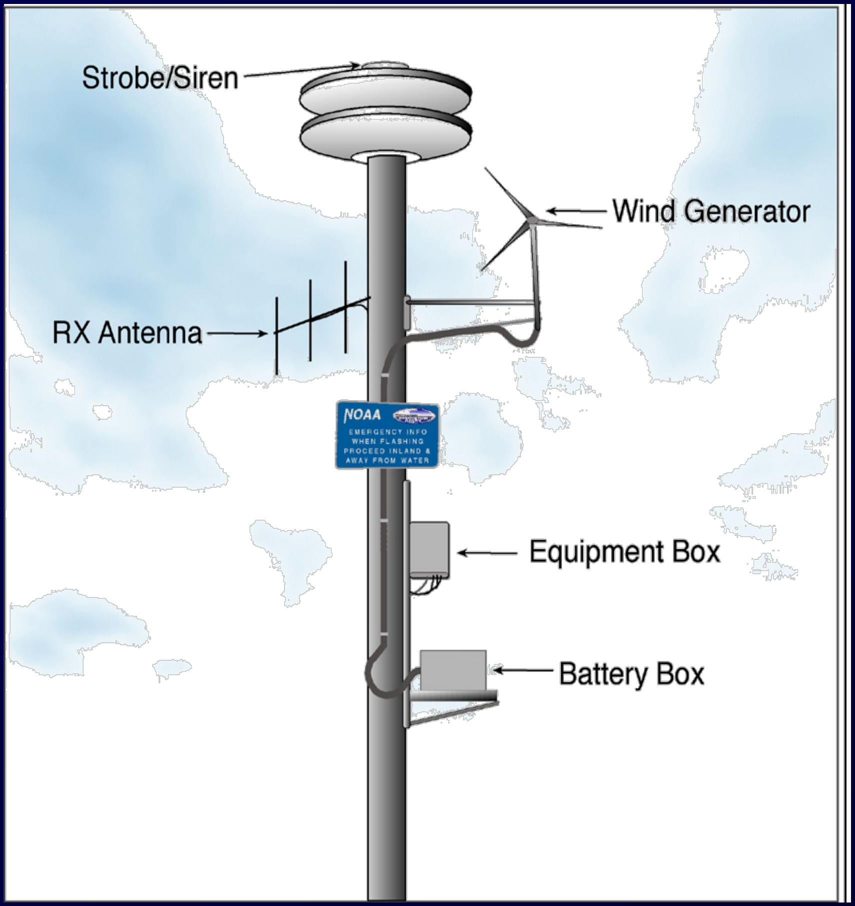
NOAA Weather Radio
Local transmitters

Tsunami Warning / Evacuation Communications Cycle



AHAB Radio

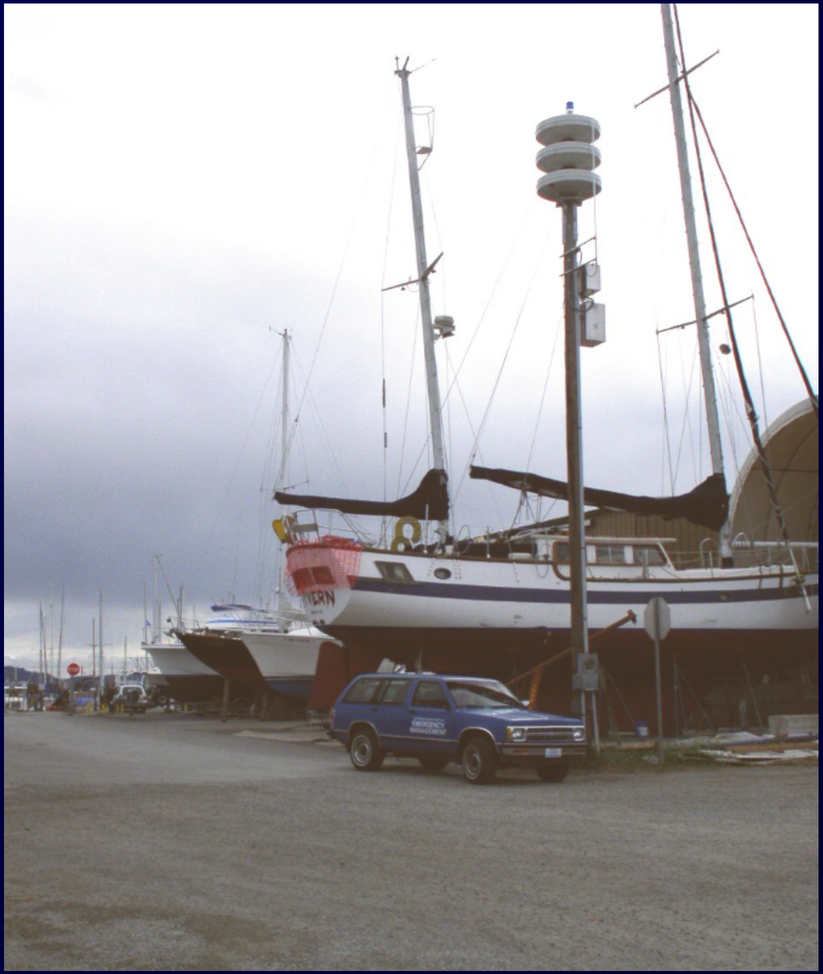
- Washington Emergency Management and Federal Signal Partnership
- Withstands gal-force winds and salt corrosion with little to no maintenance
- Battery operated. Charged by:
  - Electrical
  - Wind
  - Solar



Concept drawing of AHAB Radio

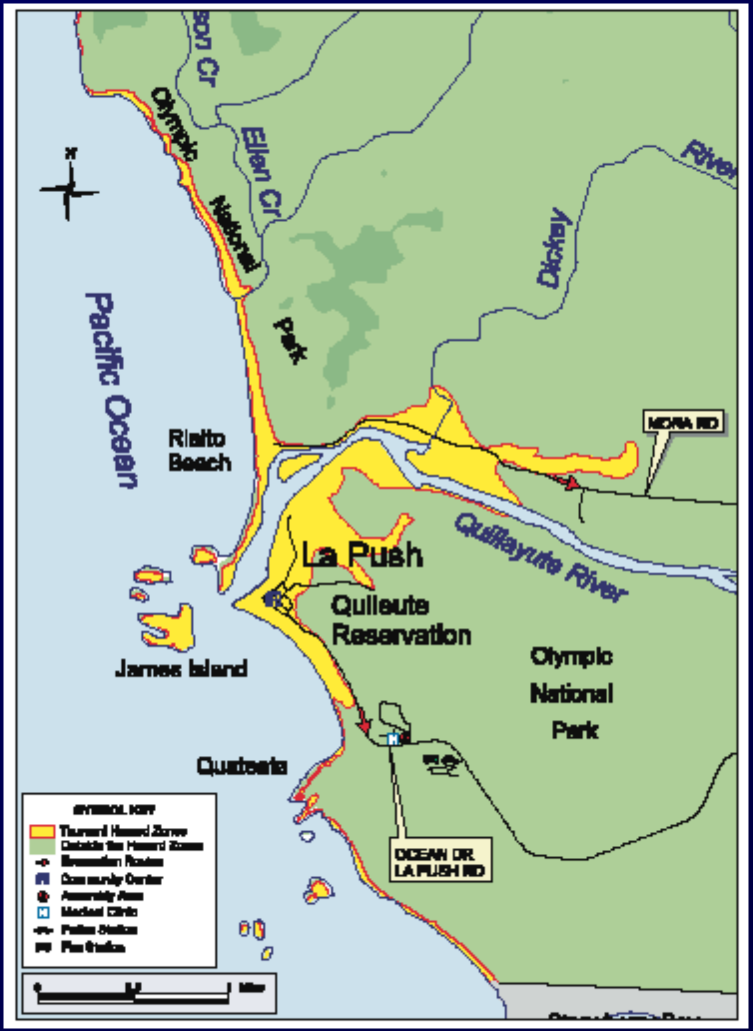
AHAB Radio

- Modulator siren – 360 Degree
- An intense blue light activated to further indicate that the area is under a hazardous situation
- Can be activated via:
    - National authorities
    - State/local emergency management
    - Other communication protocols

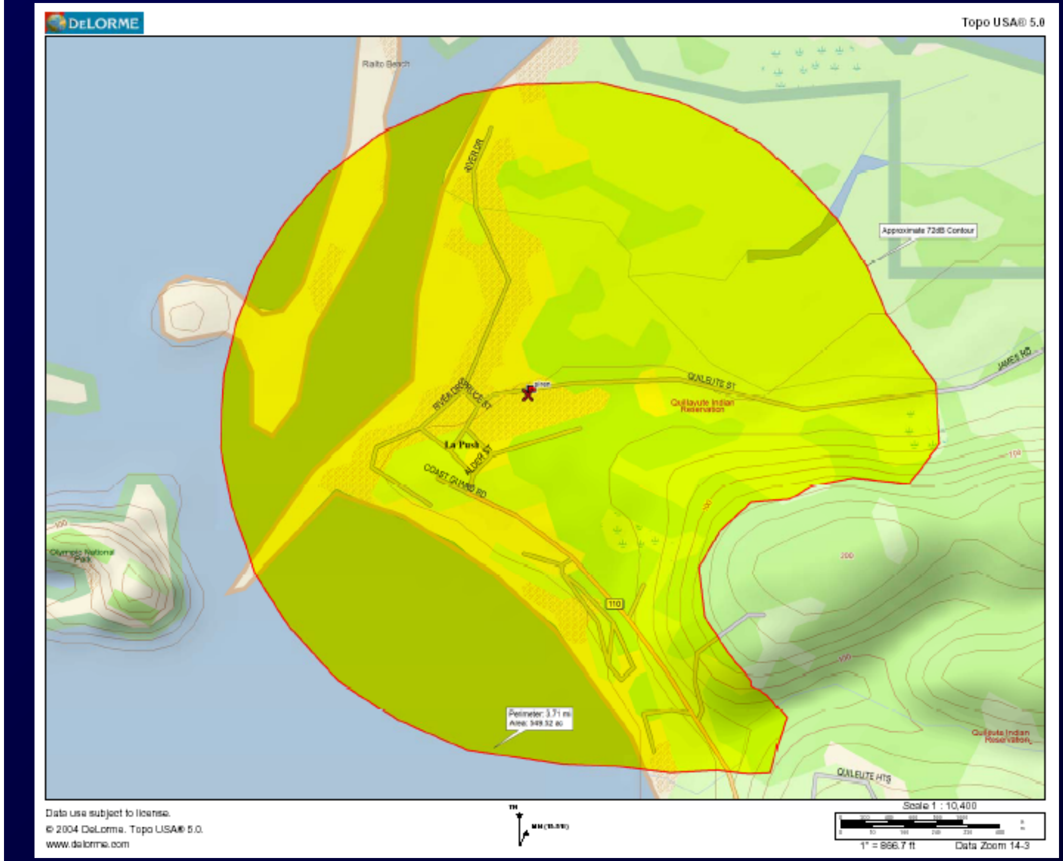


Installed Oct 30, 2003
Port of Port Townsend

Process for Developing Coverage Area



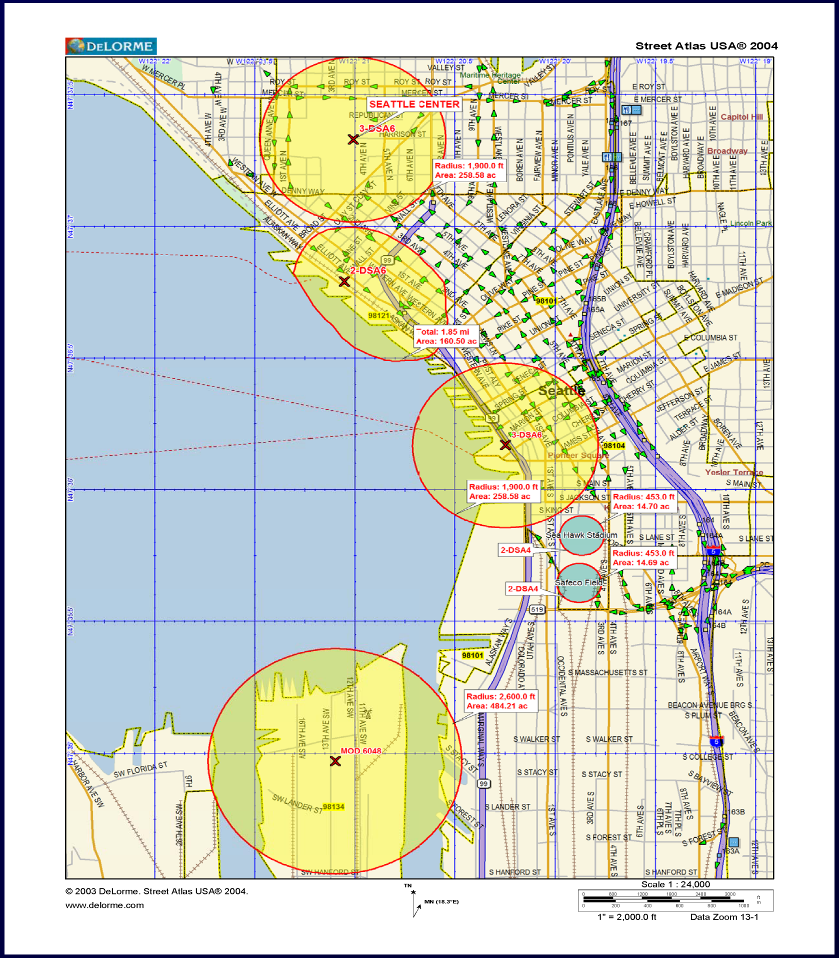
Evacuation Map



Coverage Area Map

Results

- Provide rapid and effective warning to areas of high risk to both man-made and natural hazards
- Take advantage of several funding programs to merge several technologies
- Take advantage of existing communication protocols
- Take advantage of voice messaging technology and local activation of AHAB Radio



Seattle AHAB Radio Project uses seismic instruments, cameras, a weather station, and chemical detectors

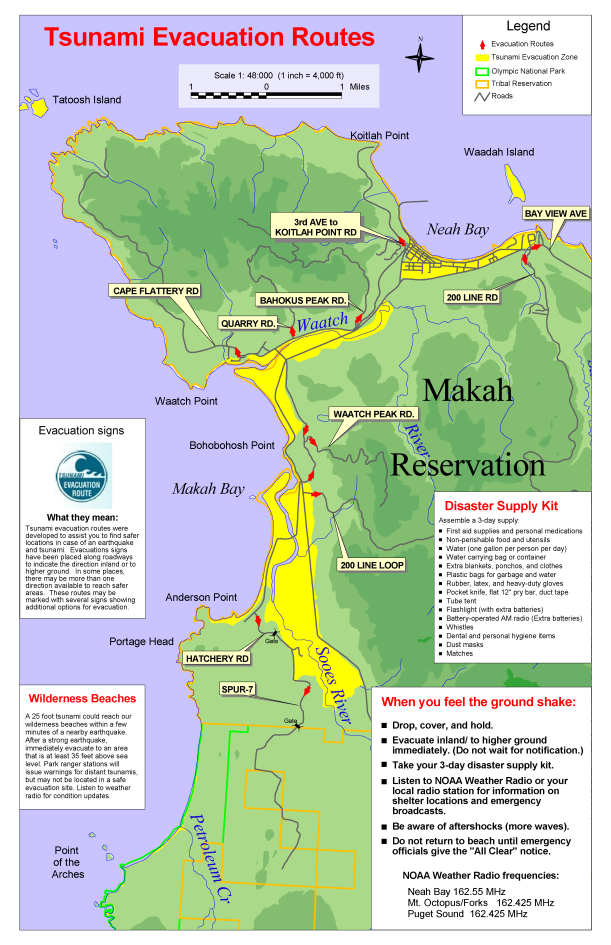
2004 National Earthquake Conference Award of Excellence – Category: Response

Tsunami Ready Community

For a community to start the planning process, their risk and vulnerability has to be addressed

- ➢Define sources
- ➢Tsunami Numerical Modeling
- ➢Tsunami Inundation Maps
- ➢Tsunami Evacuation Maps
- ➢Evacuation Modeling

"Local tsunami evacuation maps developed based on modeling, tsunami inundation maps and local oral history."



Evacuation signs

What they mean:

Tsunami evacuation routes were developed to assist you to find safer locations in case of an earthquake and tsunami. Evacuations signs have been placed along roadways to indicate the direction inland or to higher ground. In some places, there may be more than one direction available to reach safer areas. These routes may be marked with several signs showing additional options for evacuation.

Wilderness Beaches

A 25 foot tsunami could reach our wilderness beaches within a few minutes of a nearby earthquake. After a strong earthquake, immediately evacuate to an area that is at least 35 feet above sea level. Park ranger stations will issue warnings for distant tsunamis, but may not be located in a safe evacuation site. Listen to weather radio for condition updates.

Disaster Supply Kit

Assemble a 3-day supply:

- First aid supplies and personal medications
- Non-perishable food and utensils
- Water (one gallon per person per day)
- Water carrying bag or container
- Extra blankets, ponchos, and clothes
- Plastic bags for garbage and water
- Rubber, latex, and heavy-duty gloves
- Pocket knife, flat 12" pry bar, duct tape
- Tube tent
- Flashlight (with extra batteries)
- Battery-operated AM radio (Extra batteries)
- Whistles
- Dental and personal hygiene items
- Dust masks
- Matches

When you feel the ground shake:

- **Drop, cover, and hold.**
- **Evacuate inland/ to higher ground immediately. (Do not wait for notification.)**
- **Take your 3-day disaster supply kit.**
- **Listen to NOAA Weather Radio or your local radio station for information on shelter locations and emergency broadcasts.**
- **Be aware of aftershocks (more waves).**
- **Do not return to beach until emergency officials give the "All Clear" notice.**

NOAA Weather Radio frequencies:

Neah Bay 162.55 MHz
Mt. Octopus/Forks 162.425 MHz
Puget Sound 162.425 MHz

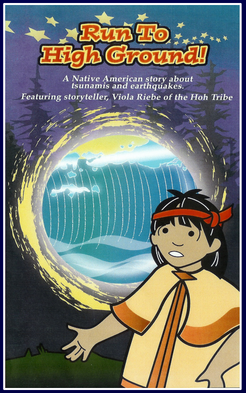
Tsunami Ready Community

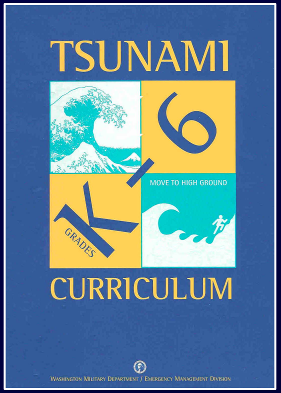
Through tsunami mapping communities develop assembly areas

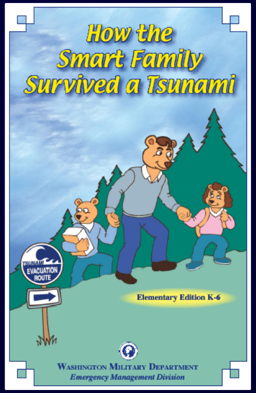
- ❖ BUT No high ground?
  - ➢Vertical evacuation
  - ➢Construction guidance

Tsunami Ready Community

- Public education cornerstone to success
  - Risk communications -- key to how people will respond
  - Exercise and drill response plans
    - Actual exercises and/or drills (includes amateur radio)
    - Train on the use of tsunami tools
  - Social science must be part of the tsunami ready process


Run To High Ground!
A Native American story about tsunamis and earthquakes.
Featuring storyteller, Viola Riebe of the Hoh Tribe


TSUNAMI
K-6
GRADES
MOVE TO HIGH GROUND
CURRICULUM
Washington Military Department / Emergency Management Division


How the Smart Family Survived a Tsunami
TSUNAMI EVACUATION ROUTE
Elementary Edition K-6
Washington Military Department
Emergency Management Division

Tsunami Ready Community

- Community buy-in has to take place to have a successful Tsunami Ready Program
  - Apply Growth Management principles to reduce impact of a Tsunami on lives and infrastructure

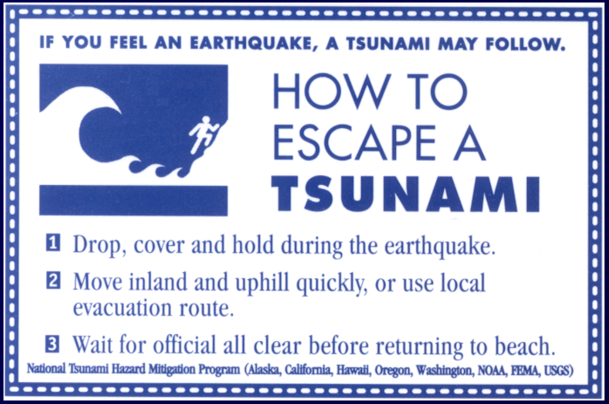
Entering A TsunamiReady Community
IN CASE OF EARTHQUAKE, GO TO HIGH GROUND OR INLAND
A StormReady Community
2000 - 2002

Ocean Shores

Long Beach

Tsunami Ready Community

- Engaging business community saves lives
  - ➢Tourist must be aware of tsunami issues and evacuation procedures
  - ➢Educate and train business on tsunami contingency planning and train staff on what to do for a tsunami



IF YOU FEEL AN EARTHQUAKE, A TSUNAMI MAY FOLLOW.

HOW TO ESCAPE A **TSUNAMI**

1 Drop, cover and hold during the earthquake.

2 Move inland and uphill quickly, or use local evacuation route.

3 Wait for official all clear before returning to beach.

National Tsunami Hazard Mitigation Program (Alaska, California, Hawaii, Oregon, Washington, NOAA, FEMA, USGS)

Shilo INNS

Tsunami!

Evacuation Map for Ocean Shores and Vicinity

Safety Tips for the Washington Coast

Tsunami Ready Community

- Integrated on-shore communications infrastructure must be in place to get the message to the public
  - Communication infrastructures to support alert and notification system need to be in place to make these system effective and reliable
  - An indoor alert and notification system for public facilities, homes and businesses will facilitate warning and evacuation
  - An outdoor alert and notification system for tsunami communities to warn the public on beaches or high traffic areas
  - Amateur Radio is a part of this whole process

No Overnight Solutions

Accept and Embrace Generational Lessons

"Become the change you want to see in the world"

Questions ???